

ANALYSIS OF OFF-SHORE FUEL HANDLING TECHNOLOGY(U) BDM  
CORP MCLEAN VA F J HAMLIN ET AL. DEC 85  
BDM/W-85-816-TR DAAK70-83-D-0019

CORP MCLEAN VA F J HAMLIN ET AL. DEC 85  
BDM/W-85-816-TR DRAK70-83-D-0019

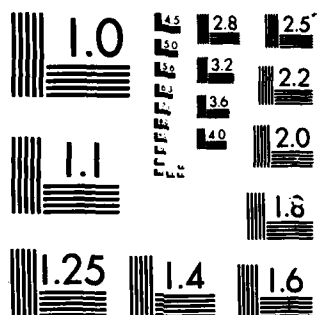
F/G 21/4

NL

END

## FILM

679



AD-A163 304

**BDM**  
THE BDM CORPORATION

7915 Jones Branch Drive, McLean, Virginia 22102-3396 • (703) 821-5000 • Telex: 901103 BDM MCLN

# Analysis of Off-Shore Fuel Handling Technology

## Final Report

DTIC  
ELECTE  
JAN 27 1986  
S D

PREPARED FOR THE LOGISTICS SUPPORT LABORATORY, U.S. ARMY,  
BELVOIR RESEARCH AND DEVELOPMENT CENTER

OTIC FILE COPY

DECEMBER 1985

BDM/W-85-816-TR

8 5 1 2 3 0 1 1 0




7915 Jones Branch Drive, McLean, Virginia 22102-3396 • (703) 821-5000 • Telex: 901103 BDM MCLN

**ANALYSIS OF OFF-SHORE  
FUEL HANDLING TECHNOLOGY -  
FINAL REPORT  
December 1985**

BDM/W-85-816-TR

Authorization for the research was Contract Number DAAK70-83-D-0019 T.O. No. 0034 (Task Order to a competitive contract awarded on a Technical Basis). The views, opinions, and/or findings contained in this report are those of the author and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other documentation.

This technical report is being submitted to Belvoir Research and Development Center, Fort Belvoir, Virginia 22060.



UNCLASSIFIED  
SECURITY CLASSIFICATION OF THIS PAGE

AD-A163304

REPORT DOCUMENTATION PAGE				
1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED		1b. RESTRICTIVE MARKINGS --		
2a. SECURITY CLASSIFICATION AUTHORITY --		3. DISTRIBUTION/AVAILABILITY OF REPORT To be determined by Army		
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE --				
4. PERFORMING ORGANIZATION REPORT NUMBER(S)		5. MONITORING ORGANIZATION REPORT NUMBER(S)		
6a. NAME OF PERFORMING ORGANIZATION The BDM Corporation	6b. OFFICE SYMBOL (if applicable)	7a. NAME OF MONITORING ORGANIZATION Belvoir R&D Center		
6c. ADDRESS (City, State, and ZIP Code) 7915 Jones Branch Drive McLean, Virginia 22102		7b. ADDRESS (City, State, and ZIP Code) Fort Belvoir, Virginia 22060		
8a. NAME OF FUNDING/SPONSORING ORGANIZATION Belvoir R&D Center	8b. OFFICE SYMBOL (if applicable) STRBE-GS	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER DAAK70-83-D-0019		
8c. ADDRESS (City, State, and ZIP Code) Fort Belvoir, Virginia 22060		10. SOURCE OF FUNDING NUMBERS		
		PROGRAM ELEMENT NO. --	PROJECT NO. --	TASK NO. 0034
		WORK UNIT ACCESSION NO. --		
11. TITLE (Include Security Classification) Analysis of Off-Shore Fuel Handling Technology				
12. PERSONAL AUTHOR(S) Hamlir, F. J., Jones, M. E., Durfee, J. H.				
13a. TYPE OF REPORT Final Technical Report	13b. TIME COVERED FROM MAY 85 TO OCT 85	14. DATE OF REPORT (Year, Month, Day) 1985 DEC	15. PAGE COUNT 86	
16. SUPPLEMENTARY NOTATION				
17. COSATI CODES		18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)		
FIELD	GROUP	SUB-GROUP		
		Supply-Class III Over-the-Shore-Logistics		
		Bulk POL		
		Logistic Support		
19. ABSTRACT (Continue on reverse if necessary and identify by block number) This report describes the current Army method for delivery of bulk fuels over the shore in an undeveloped theater and details deficiencies in the system. Also described are programmed improvements in the near term intended to correct certain deficiencies with regard to contingency planning requirements. The report discusses long term needs relative to off-shore fuel handling technology for the Army 21 concept of operations and outlines shortfalls in the system for meeting those needs. Several alternative concepts are proposed to alleviate shortfalls. Conclusions and recommendations are presented.				
20. DISTRIBUTION/AVAILABILITY OF ABSTRACT <input type="checkbox"/> UNCLASSIFIED/UNLIMITED <input checked="" type="checkbox"/> SAME AS RPT <input type="checkbox"/> DTIC USERS		21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED		
22a. NAME OF RESPONSIBLE INDIVIDUAL		22b. TELEPHONE (include Area Code)		22c. OFFICE SYMBOL

DD FORM 1473, 84 MAR

83 APR edition may be used until exhausted.  
All other editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE  
UNCLASSIFIED

# THE BDM CORPORATION

## FOREWORD

This report is submitted to the U.S. Army Belvoir Research and Development Center, Fort Belvoir, Virginia by The BDM Corporation, 7915 Jones Branch Drive, McLean, Virginia.

The report describes the system presently employed by the Army for delivering bulk petroleum products over the shore and identifies deficiencies recognized in the system. The report also discusses programmed improvements in the system designed to meet near term contingency requirements, and long term needs for the period following year 2000. Alternative concepts are proposed for offshore bulk liquid discharge, product transport to shore, and on-shore storage of fuels.

Accession For	
NTIS CRA&I	<input checked="checked" type="checkbox"/>
DTIC TAB	<input type="checkbox"/>
Unannounced	<input type="checkbox"/>
Justification	
By <i>ltr. on file</i>	
Distribution/	
Availability Codes	
Dist	Avail and/or Special
A-1	



TABLE OF CONTENTS

<u>Chapter</u>		<u>Page</u>
	FOREWORD	iii
	TABLE OF CONTENTS	v
	LIST OF FIGURES	vii
I	EXECUTIVE SUMMARY	I-1
	A. SUMMARY OF REPORT	I-1
	1. Introduction	I-1
	2. Program Approach	I-1
	3. Current Off-Shore Fueling System Description and Deficiencies	I-2
	4. Near-Term Improvements	I-3
	5. Long-Term Needs	I-4
	6. Shortfalls in Off-Shore Systems	I-4
	7. Alternative Concepts	I-7
	B. ORGANIZATION OF THE REPORT	I-8
II	INTRODUCTION	II-1
	A. BACKGROUND	II-1
	B. OBJECTIVE	II-3
	C. PROGRAM APPROACH	II-3
III	CURRENT OFF-SHORE FUELING SYSTEM	III-1
	A. CURRENT SYSTEM DESCRIPTION	III-1
	1. General	III-1
	2. Facilities	III-1
	3. Tactical Marine Petroleum Terminal (TMPT)	III-3
	B. DEFICIENCIES IN CURRENT SYSTEM	III-4
	C. DEFICIENCY SUMMARY	III-20
IV	NEAR-TERM PROGRAMMED IMPROVEMENTS	IV-1
	A. GENERAL	IV-1
	B. MOORING SYSTEMS	IV-2
	C. PIPELINE SYSTEMS	IV-5
	D. ON-SHORE STORAGE	IV-5
	E. SUMMARY	IV-6

TABLE OF CONTENTS (CONTINUED)

<u>Chapter</u>		<u>Page</u>
V	LONG-TERM NEEDS	V-1
	A. FUELING SUPPORT FOR ARMY 21	V-1
	1. General	V-1
	2. Fueling Support Operations	V-3
	B. SHORTFALLS IN OFF-SHORE SYSTEMS	V-9
	C. ALTERNATIVE CONCEPTS	V-11
	1. Rapid Deployment, Lightweight SPM	V-11
	2. High Mobility Transfer	V-12
	3. Expedient On-Shore Storage	V-14
	4. Off-Shore Storage	V-14
	5. Air-Deliverable Fuel Modules	V-15
VI	CONCLUSIONS AND RECOMMENDATIONS	VI-1
	A. CONCLUSIONS	VI-1
	B. RECOMMENDATIONS	VI-1



## LIST OF FIGURES

<u>Figure</u>		<u>Page</u>
I-1	Future Off-Shore Petroleum Distribution System	I-5
III-1	Army Bulk Petroleum Delivery in LOTS Current System	III-2
III-2	Current Off-Shore Petroleum Distribution System	III-5
III-3	Current System Deficiencies	III-19
III-4	Inability to Maintain Secure Position for Off-Shore Mooring Facility	III-21
III-5	Ship-to-Shore Fuel Transport Systems Deficiencies	III-22
III-6	Inadequate On-Shore Fuel Storage Systems	III-23
IV-1	Single Anchor Leg Mooring	IV-4
IV-2	Near-Term Future System	IV-7
IV-3	Near-Term Off-Shore Petroleum Distribution System	IV-9
V-1	Army 21 Doctrinal Theater Layout	V-2
V-2	Fueling Support Chain for Army 21	V-4
V-3	Future Off-Shore Petroleum Distribution System	V-8
V-4	Off-Shore Bulk Fuel Storage Alternatives	V-16

CHAPTER I  
EXECUTIVE SUMMARY

A. SUMMARY OF REPORT

1. Introduction

The Army currently has an air-transportable mooring/pipeline system capable of mooring tankers up to the 25,000 deadweight ton (DWT) class and delivering 600 gallons per minute (gpm) from up to 5000 feet off-shore. Nevertheless, a mission area analysis (MAA) has identified as a continuing deficiency in this system, the inability of the Army to supply adequate bulk fuel over-the-shore for the support of military operations.

A variety of actions is being taken by the Army to correct known deficiencies and provide a more capable system. These consist of the development of a military capability to conduct off-shore fuel transfer from tankers up to 70,000 deadweight tons, a pipeline for use up to four miles between the tanker and the shore, with a daily throughput of 30,000 barrels of petroleum, all under more severe environmental conditions than those which limit the performance of the current system. Belvoir Research and Development Center is also conducting exploratory development through contract for a 25,000 to 50,000 bbl fuel storage tank for on-shore fuel storage.

2. Program Approach

The study was conducted in two phases. In Phase I a list of definitive system requirements was prepared and detailed deficiencies in the present Army capability were identified from a variety of sources.

A detailed examination of shortfalls, including the issue of survivability, was initiated in Phase II. Alternative systems and solutions to shortfalls were identified and/or conceptualized. Emphasis was placed on fueling support for Army 21 during this phase to insure that solutions were geared to long term needs.

During the course of this phase, it was concluded that the other ongoing Army and Navy programs would have a considerable impact on the nature of alternatives developed and the preparation of meaningful R&D programs. This would affect the work remaining in the study. Thus, it was determined that the study would be abbreviated and the scope more limited than originally intended. The results of this somewhat reduced effort is summarized in the paragraphs below.

3. Current Off-Shore Fueling System Description and Deficiencies

In the current system, Army petroleum supply in an amphibious operation begins with the receipt of bulk fuel from offshore petroleum tankers in over-the-shore operations using an Army Tactical Marine Petroleum Terminal (TMPT). System facilities are divided into three categories; tanker mooring facilities, ship-to-shore transport, and on-shore storage. The Army has two types of mooring systems, one which uses drag embedment anchors or concrete block anchors, and a second system which uses propellant embedment anchors. Ship-to-shore transport of the bulk fuel may be by six-inch floating hose line or by six-inch bottom-laid pipeline. On-shore storage is accomplished using a network of 50,000 gallon collapsible fabric tanks connected by hose lines, pumps and filters for distribution of the products received. The TMPT is installed and operated by a Petroleum Pipeline and Terminal Operating Company (onshore portion), and an Engineer Port Construction Company (offshore portion). The system is designed to be operational within a 72 hour time frame. The TMPT has a storage capacity of approximately 3,000,000 gallons (71,400 barrels) dispersed over a 160 acre area on-shore. A pumping station using a 600 gpm pump is at the shoreline to distribute fuel coming ashore to a series of tank modules.

Deficiencies in the U.S. Army's capability to deliver fuel in bulk to an undeveloped theater may be summarized in three categories:

- (1) Inability to maintain secure position for off-shore mooring of tanker,
- (2) Ship-to-shore fuel transport systems do not meet modern warfare requirements, and
- (3) On-shore fuel storage systems are inadequate.

4. Near-Term Improvements

As a result of needs identified, principally with rapid deployment concepts and theaters of operation associated with near term contingencies, initiatives have been taken to upgrade the Army over-the-shore bulk fuel delivery capability. These initiatives will result in procurement actions for state-of-the-art materiel which are intended to satisfy near to mid-term requirements.

Two mooring systems will be acquired. The first, a propellant embedded anchor mooring system (PEAMS) will provide capabilities to moor vessels up to 40,000 deadweight tons in depths from 15 ft to 120 ft in a sea-state 4 condition with a current of four knots within 10 degrees of the longitudinal axis of the tanker and a 30-knot wind abeam. It will be capable of surviving sea-state 7, wave height of 30 ft, current of four knots, winds of up to 55 knots, and a 10 ft tide without tanker being hooked up. It will be capable of being installed within 72 hours. The system is similar in design and function to the multi-leg mooring system currently being employed by the Army but will be capable of improved operating limits.

The second system being acquired is the single anchor leg mooring system (SALM), which will provide, at a minimum, capabilities to moor a 70,000 deadweight ton tanker in a sea state 5 condition with a current of four knots. It will be capable of providing 1000 gallons per minute of bulk liquid thru its manifold and also be capable of being installed within 72 hours. The SALM is a floating platform that is towed to the area of employment by a tanker or ocean-going tug. The platform is sunk by flooding ballast tanks causing the platform to rest on the ocean floor. The system includes flexible pipe to tie into the ship-to-shore pipeline and approximately 600-800 feet of tanker hose.

Two bulk liquid ship-to-shore pipelines will be acquired; a one mile system and a four mile system. Both systems will be capable of being installed within 72 hours and providing at least 600 gpm at a distance of one mile off shore. With one or more lines, it will be capable of providing up to 1200 gpm within 216 hours at a distance of four miles off shore. It will be capable of operating at depths up to 120 feet.

## THE BDM CORPORATION

On-shore storage will be accomplished by the use of a tactical petroleum terminal (TPT) which will consist of the equipment necessary to receive, store, and issue multi-product bulk petroleum in an over-the-shore operation. The TPT will have a receipt and storage capability of 3,600,000 gallons.

Although near term development and acquisition programs improve the Army's capability measurably, it is premature to assess the ability of the near term system to solve completely all of the deficiencies now existing. Variations in off-shore bottom gradient, wind force and direction, tidal ranges, sea bottom geology, exposure of the shoreline to swell conditions, off-shore reefs and other factors will introduce different demands in mooring systems, ship-to-shore transport, and on-shore storage, than those being addressed in the near term.

5. Long-Term Needs

As stated earlier, this study examines principally long term needs relative to off-shore fuel handling technology for the Army 21 concept of operations. Several important changes in fueling support for Army 21 versus the current system (Army 86) can be anticipated.

Figure I-1 illustrates the dispersal of beach heads in the Army 21 concept using concealment techniques and decoy operations. Multiple beach heads will require logistic support to each of the beach heads. This may, in fact, call for the use of smaller tankers or barges to support each beach head or the tanker moving successively from one beach head to the next to provide the necessary POL. Standoff distances may still be greater than present contingency plans provide for depending upon the geography of the area. Petroleum transfer must be dependable despite rough seas, high winds, strong currents, or large tidal changes. In the interest of survivability, mooring the tanker in a conventional manner might not be desirable and the supply system must be capable of adapting to theater needs and conditions.

6. Shortfalls in Off-Shore Systems

Vulnerability of the off-shore fuel handling system to attack from longer range enemy weapon systems may be a serious deficiency. Vulnerability varies considerably depending on the scenario and enemy

# FUTURE OFFSHORE PETROLEUM DISTRIBUTION SYSTEM

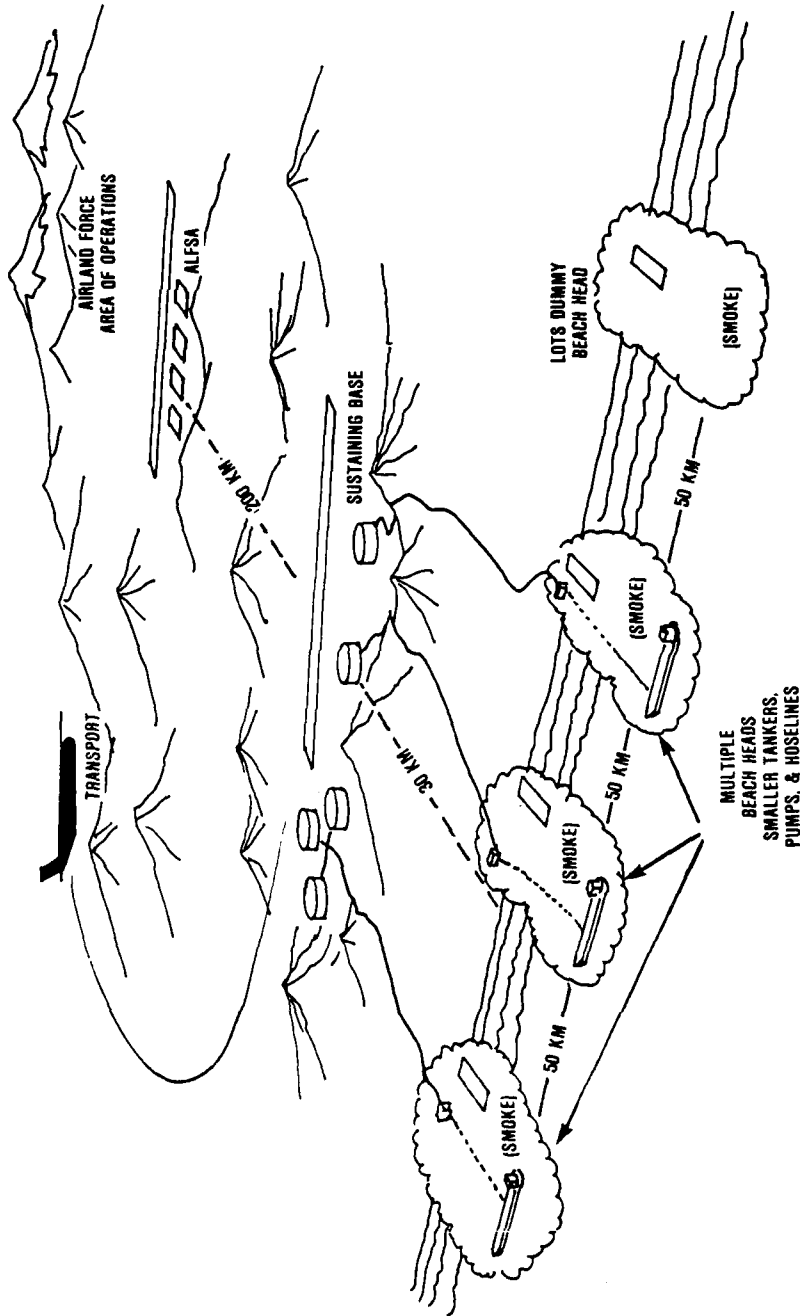


Figure I-1. Future Off-Shore Petroleum Distribution System

## EXECUTIVE SUMMARY

## THE BDM CORPORATION

capabilities to mount an attack. Dispersal of on-shore storage to a number of relatively small, widely dispersed tank farms will enhance survivability but will increase the complexity of the POL support system, and will add to cost and operating personnel.

The systems under development to satisfy near term contingency requirements are predicated on specific geographical and environmental conditions. The degree to which near term improvements will be adequate to satisfy long-term needs in all theaters of operation has yet to be determined.

Up to 30,000 barrels (1.26 million gallons) per day of bulk liquid must be transported up to four miles offshore. Several different petroleum products must be moved through the same, or adjacent, pipeline placing additional demands on the system.

Current methods for fuel storage on-shore in an undeveloped theater specify a period of 72 hours to install the system. Since a complete TMPT on-shore portion has never been installed there is speculation as to whether or not it can be accomplished in 72 hours.

Inasmuch as the on-shore storage takes place in collapsible fabric tanks, the system is vulnerable to failure or damage due to enemy action. Rupture of the tanks can easily result from shrapnel damage or small arms hits. Also, due to the relatively large amount of acreage of level terrain needed for the system, siting the storage area poses some special problems.

In summary, the PEAMS or the SALM mooring system, coupled with the TMT on-shore storage system, all of which are now undergoing development and testing, may well solve many of the problems existing today and possibly many for the future. Particularly, the combined system may prove out in such areas of concern as capacity or time of installation. Also, future improvements may be made to increase such capabilities of the system. It is considered unlikely, however, that the survivability of the overall system, as now envisioned, can be significantly enhanced. It will always be vulnerable to enemy air or missile attack because it is a stationary, concentrated, soft target.

7. Alternative Concepts

The following alternative concepts for handling bulk fuels in an off-shore scenario in an undeveloped theater are proposed. These concepts would serve to increase and disperse the OTS fueling facilities, thus reducing the vulnerability of the total system. This is particularly important during the early stages of a contingency operation. This would probably be the first seven to ten days or until the lodgement area is relatively secure from threat air and missiles.

a. Rapid Deployment, Lightweight SPM

A dedicated landing craft with ocean going capability could be outfitted to transport and support the total installation. A single point mooring (SPM) buoy weighing less than 60 tons would be transported and launched by the landing craft. With appropriate modification of the cargo deck the buoy could be launched and set by the landing craft without the need for heavy lifting equipment. Chain mooring would be self-contained with the buoy installation. Ship-to-shore transport of the fuel would be accomplished through flexible six- or eight-inch aluminum or plastic pipeline stored on reels mounted vertically or horizontally on the deck of the landing craft. Pumping would be accomplished using the tanker's main cargo pumps.

b. High Mobility Transfer

This concept would employ portable bulk fuel tanks on the deck of an air cushion vehicle (ACV); a LACV-30, the proposed LAMP-H, or the U.S. Navy LCAC for ship-to-shore transport of petroleum products. POL would be pumped from the tanker into the portable tanks on the deck of the ACV, transported to shore, and pumped out of the portable tanks at a discharge point into an on-shore storage system. A fleet of four LACV-30s could transport 1500 barrels of fuel in a 20 hour day. Two Navy LCACs, with a higher speed and larger cargo capacity, could transport nearly 1800 barrels of fuel in a 20 hour day.

c. Expedient On-Shore Storage

Temporary storage on-shore could be established by any one or combination of several different means. A rapidly constructed storage tank could be made with earthmoving equipment by excavating an open pit



surrounded by a berm constructed of the excavation spoil. The pit would be lined with a fuel-impervious fabric to contain the fuel. Another means of storage would consist of two plastic/fibre reinforced plastic molded hemispheres, or half-cylinders with their ends closed, that could be quickly assembled and sealed by adjoining flanges to provide a storage tank. The shells could be nested one within the other in quantity to reduce storage and handling when not in use.

d. Off-Shore Storage

A barge sunk to the bottom in relatively shallow water is a ready-made, rapid means of establishing a storage system which is not dependent upon terrain preparation or a large amount of manpower to assemble. Floating barges or tankships offer considerable potential for a large, mobile fuel supply. LASH or SEABEE barges configured for bulk liquid storage could be easily transported to the operational site by their parent ship along with other early logistic support items. Fabrication of tanks conforming to the interior size of a LASH or SEABEE barge could also be accomplished so that any LASH/SEABEE barge could be temporarily used for bulk fuel storage.

e. Air-Deliverable Fuel Modules

The ability to air deliver a modular fuel package with self-contained pump from a tanker moored off-shore in theater would satisfy the need for a more mobile resupply system in forward areas, and would provide an effective means for reconstituting a damaged fuel distribution system. Air delivery by helicopter could be effected direct from the supply tanker off-shore to tactical fueling points and would be highly flexible in changing battle situations.

B. ORGANIZATION OF THE REPORT

Chapter II provides an introduction to the study. Background to the problem of handling fuels off-shore for logistic support of a deployed force is outlined and the objective of the study is stated. The program approach is also described to inform the reader of the methodology employed and indicate the scope of the effort.

## THE BDM CORPORATION

A description of the system currently used by the Army for transferring bulk fuel from a supply tanker off-shore to a storage area on-shore is provided in Chapter III. Deficiencies in the current system as obtained from a variety of documents and undocumented sources are listed in detail. Sources are identified.

Next, Chapter IV describes programmed improvements in the Army's capability for handling bulk fuel in the near term to meet stated contingency requirements. Mooring systems for supply tankers, ship-to-shore pipelines, and on-shore storage capabilities are discussed. Improvements covered encompass those being conducted by the U.S. Army and the U.S. Navy.

Chapter V discusses the long-term needs for fueling support in the Army 21 concept. The target era for Army 21 is from the year 2000 to the year 2015. In consideration of the fueling support requirements described, shortfalls in off-shore fueling systems for Army 21 are identified and discussed. Alternative concepts are then proposed to eliminate shortfalls or provide new approaches to meeting needs.

Chapter VI summarizes the conclusions reached by the study team and makes recommendations for Army consideration.

CHAPTER II  
INTRODUCTION

A. BACKGROUND

The Army currently has an air-transportable mooring/pipeline system capable of mooring tankers up to the 25,000 deadweight ton (DWT) class and delivering 600 gallons per minute (gpm) from up to 5000 feet off-shore. Nevertheless, a mission area analysis (MAA) has identified as a continuing deficiency in this system, the inability of the Army to supply adequate bulk fuel over-the-shore for the support of military operations.

One of the earliest attempts to develop such a capability in the post World War II era resulted in the creation of the tactical marine terminal (TMT) to support logistic operations in Vietnam. Although procurement of TMT components was begun in 1965, permanent port facilities had been established at the site where the terminal was to be used by the time procurement was completed. Except for the collapsible fabric tanks that made up the on-shore storage portion of the terminal, the remaining components were placed in storage without ever being employed. The characteristics of the system, however, were established and made a part of Army doctrinal publications. Future use of the TMT was established as a result of the study of Army petroleum logistics in 1977 by the U.S. Army Quartermaster School in Fort Lee, Virginia. A void in the Army's ability to distribute bulk petroleum in an undeveloped theater was identified in this study. The study acknowledged that fixed port facilities, pumping stations and pipeline networks existed in more highly developed areas of the world, e.g., Western Europe. But, the study also concluded that in other parts of the world, notably Africa, the Middle East, and Southeast Asia, no such facilities were available. Since these areas had taken on new significance in recent years as potential areas of military conflict, the need for a tactical marine terminal, or similar facility, would likely be required to support contingency military operations in these areas. The TMT, or a more advanced system using the same concept,

## THE BDM CORPORATION

could provide the means to offload ocean-going tankers and distribute the bulk petroleum needed by U.S. or allied forces ashore.

The early TMT was soon recognized as inadequate to meet the Army's emerging needs. It lacked deployability and installation of the system was very manpower intensive. The pipeline or hoseline used to transport the liquid petroleum products from tanker to shore created a substantial logistic burden and was limited to use over distances a mile or less between the ship and the shoreline and required extensive dedicated equipment for installation.

The multi-leg mooring system (MLMS) was developed in response to these deficiencies. Although the multi-leg mooring system provided no increased performance capability over that of the TMT, the logistical burden was substantially reduced since propellant embedded anchors are used in place of the heavy drag anchors and chain, and the installation equipment is lightweight and air transportable. Based on the 1977 QM School study, multi-leg mooring systems were procured and the bulk fuel tank assembly (BFTA) was developed and procured. The BFTA has a capacity of 5000 barrels (210,000 gallons) which enhances the TMT and other on-shore fuel storage facilities. In addition, exploratory development for a rapidly erectable 25,000 to 50,000 bbl storage tank to provide on-shore storage has been started and Belvoir Research and Development Center has awarded a contract under 6.2 funding for such a tank. The tank probably will be a relatively low profile gravity wall filled with dirt and lined with a coated fabric.

Based on the mission area analysis (MAA) and increased interservice concern for the inability to support rapid deployment force operations, principally in Southwest Asia, the Army established an Action Officers Working Group to coordinate the Army's activities with the Navy. The Navy was designated as the lead service in the acquisition of a single point mooring (SPM) system to accommodate tankers up to the 70,000 DWT class and a ship-to-shore pipeline system capable of delivering 30,000 bbl per day

## THE BDM CORPORATION

at distances up to 4 miles from shore. Additionally, the Army is developing a propellant embedded anchor mooring system (PEAMS) capable of holding a 40,000 DWT tanker and a 1 mile ship-to-shore pipeline which will be less labor intensive than the current 5000 foot system. The Navy has no requirement for these two systems.

The deficiency cited in the first paragraph is attributed to the Army, however, it must be recognized that a common problem is faced by all the military services. It is particularly acute for the U.S. Navy and Marine Corps. Independent research is being performed by the Navy to reach a solution keyed to Navy and Marine Corps requirements. This research is being closely monitored by the Army.

### B. OBJECTIVE

The objective of this analytic effort is to assess current commercial and military over-the-shore fuel delivery systems, to determine and evaluate shortfalls existing in these systems as compared with Army requirements, and to identify alternative solutions to those shortfalls.

### C. PROGRAM APPROACH

The program approach consisted of two phases, the first of which involved the preparation of a list of definitive system requirements as identified by Army publications and directives, and deficiencies in capability cited by a variety of official sources. A consolidated listing of deficiencies was assembled. Where requirements were driven by specific scenarios, an attempt was made to update those scenarios and revise the requirements as appropriate. Particular attention was given in the scenarios to characteristics and parameters which would exert the most influence on system performance. Such factors as tidal ranges, normal and extreme sea conditions encountered, sea bottom gradient and geology, and interface with shore terminals were considered. The current Army system was defined so that deficiencies could be better recognized. Planning

which is currently being used to develop near term system improvements or modifications was also reviewed. Apparent shortfalls in the system were identified through a comparison of deficiencies versus requirements.

At the conclusion of phase I it was recognized that some shortfalls would exist in three distinct areas:

- (1) Off-shore mooring for tankers,
- (2) Ship-to-shore transmission of POL products, and
- (3) On-shore storage of POL products.

The problem of system survivability emerged as a matter of some concern and was examined more closely in phase II.

Phase II commenced with a detailed examination of the shortfalls identified earlier. Alternative systems and solutions to shortfalls were identified and/or conceptualized. Emphasis was placed on fueling support for Army 21 during this phase to insure that solutions were geared to long term needs. This was considered an essential element of the study inasmuch as some actions were already being programmed to satisfy near term demands.

During the course of Phase II, both the BDM study team and the Belvoir R&D Center study sponsor, came to the conclusion that on-going testing, evaluation and acquisition of various tanker anchorage and fuel discharge systems under other Army and Navy programs would greatly affect the work remaining in the study. Ongoing work will have a considerable impact on the nature of alternatives developed. This impact would be primarily in the refinement of alternate solutions and, hence, the preparation of a meaningful development program. More preliminary analysis and interim findings will be needed for the near term program prior to development of long term solutions. For these reasons, a more abbreviated study with more limited scope than originally intended was conducted.

CHAPTER III  
CURRENT OFF-SHORE FUELING SYSTEM

A. CURRENT SYSTEM DESCRIPTION

1. General

In the current system, Army petroleum supply in an amphibious operation begins with the receipt of bulk fuel from offshore petroleum tankers in over-the-shore operations using an Army Tactical Marine Petroleum Terminal (TMPT). The TMPT consists of mooring equipment, floating and undersea lines and onshore flexible storage tanks. The offshore tankers may be deep-draft or coastal tankers. Coastal tankers may be used to move product from the deep-sea vessel to moorings in water too shallow for the larger tankers. Fuel is stored onshore in hastily emplaced tanks and moved inland by a combination of hoses, pipelines, and tank trucks. The initial fuel handling capabilities are expanded as soon as possible to more permanent type facilities. These may include constructed piers or jetties, steel bolted tanks, and steel pipelines.

2. Facilities

System facilities are divided into three categories; tanker mooring facilities, ship-to-shore transport, and on-shore storage and are summarized in Figure III-1. As previously indicated, the Army has two types of mooring systems; one which uses drag embedment anchors or concrete block anchors, and a second system developed recently which uses propellant embedment anchors. Ship-to-shore transport of the bulk fuel may be by 6 inch floating hose or by 6 inch bottom-laid pipeline. On-shore storage is accomplished using a network of 50,000 gallon collapsible fabric tanks connected by hoses, pumps and filters for distribution of the products received. Provision is made for the storage of three different petroleum products; mogas, diesel and JP. A recently fielded item, a 5000 barrel collapsible fabric tank termed the bulk fuel tank assembly (BFTA), will replace or supplement the 50,000 gallon tanks as the Army inventory of the BFTA increases.

**CURRENT FUEL DELIVERY SYSTEM**

- TANKER MOORING FACILITIES
  - CONVENTIONAL MOORING SYSTEM
    - 6,000 LB DRAG EMBEDMENT ANCHORS
    - OR
    - 10,000 LB CONCRETE BLOCK ANCHORS
    - ASSOCIATED CABLES/HAWSERS
  - MULTI-LEG MOORING SYSTEM (MLMS)
    - XM-50 PROPELLANT EMBEDMENT ANCHORS
    - ASSOCIATED LAUNCHING AND RECOVERY EQUIPMENT
- SHIP-TO-SHORE TRANSPORT
  - FLOATING HOSELINE
    - 100 50 FT SECTIONS OF 6 INCH RUBBER HOSE
    - ASSOCIATED INSTALLATION AND MARKING EQUIPMENT
  - SUBMARINE PIPELINE
    - 5,000 FT OF 30 FT LONG THREADED PIPE SECTIONS
    - ASSOCIATED INSTALLATION EQUIPMENT
- ONSHORE STORAGE
  - 50,000 GALLON COLLAPSIBLE STORAGE TANKS
  - OR
  - 5,000 BARREL BULK FUEL TANK ASSEMBLIES (BFTA)
  - ASSOCIATED PUMPS, FILTERS, HOSES AND FITTINGS

CAPABILITIES - 25,000 DWT TANKERS, SEA-STATE 2, CURRENT 1 KNOT 1 MILE FROM SHORE, 720,000 GALLONS THROUGHPUT IN 20 HOURS, 3 MILLION GALLONS STORAGE (17,000 BARRELS THROUGHPUT, 71,400 BARRELS STORAGE)

Figure III-1. Army Bulk Petroleum Delivery in LOTS Current System



## THE BDM CORPORATION

### a. Tanker Mooring Facilities

Moorings are located within one mile of shore, in an area suitable for using six inch submarine pipelines. Bottom topography should not have a change in slope greater than five degrees.

Multi-leg propellant embedment anchors may be used. This is a multi-leg mooring system that has the capability to be rapidly installed to meet initial requirements in an undeveloped theater. The system is installed by military personnel, and can accommodate fully loaded tankers up to 25,000 dead weight tons (DWT) in sea-state two conditions. Ship's anchors or other conventional anchors are also used with this system.

### b. Ship-to-Shore Discharge

Up to 5,000 feet of six inch floating hoses may be installed from ship to shore storage.

Up to 5,000 feet of six inch bottom-laid pipeline may be installed to supplement or replace the floating hose.

### c. Onshore Storage System

Onshore storage consists of a collection of fuel tank module assemblies using 50,000 gallon collapsible fabric tanks or 5,000 barrel bulk fuel tank assemblies (BFTA). The BFTA is a large volume, self-supporting, rapidly deployable, collapsible bulk fuel tank assembly with a capacity of 5,000 barrels, which provides the Army with the capability of deploying, establishing, and operating marine and inland bulk fuel terminals. Collapsible fabric tanks may be supplemented or replaced by bolted steel tanks of 10,000 barrel capacity.

### 3. Tactical Marine Petroleum Terminal (TMPT)

The TMPT is a receipt and storage system for over-the-shore movement of bulk petroleum into a theater of operations. It consists of some or all of the components previously described. The TMPT is installed and operated by a Petroleum Pipeline and Terminal Operating Company (onshore portion), and an Engineer Port Construction Company (offshore portion). The system is designed to be operational within a 72 hour time frame.

## THE BDM CORPORATION

Normally, the TMPT is composed of a multi-leg tanker mooring system (MLMS), offshore steel pipeline and floating hose line system (one mile), a pump station assembly, onshore hoses, seven fuel tank module assemblies, seven mobile firefighting systems, and three fuel dispensing assemblies.

The TMPT has a storage capacity of approximately 3,000,000 gallons (71,400 barrels) dispersed over a 160 acre area on-shore and one mile of six inch steel pipeline and six inch floating hose line with a multi-leg tanker mooring system off-shore.

A representative off-shore petroleum distribution system as it would be employed today is illustrated in Figure III-2. The figure shows a tanker moored with the MLMS and using 6 inch threaded pipeline laid on the sea bottom between the tanker and the shoreline. A pumping station using a 600 gpm pump is at the shoreline to distribute fuel coming ashore to a series of tank modules made up of 50,000 gallon collapsible fabric tanks. Only two tank modules are shown for simplification of the diagram. Since the system may be employed for the receipt, storage, and distribution of more than one petroleum product, there is a provision, normally at the pump station, for batch interface detection and separation of products with a slush tank to receive small quantities of product mix.

### B. DEFICIENCIES IN CURRENT SYSTEM

A variety of documented sources was used to identify deficiencies in Army capability to discharge petroleum products in bulk from a tanker offshore, and deliver the products to a storage area onshore, where established port facilities do not exist or have been damaged beyond repair. These sources included the following:

- (1) Combat Service Support Mission Area Analysis, Level II (CSSMAA-II) dated 22 April 1983 prepared by the U.S. Army Logistics Center.
- (2) Battlefield Development Plan Draft (BDP), Appendix A, "Prioritization of Mission Area Deficiencies dated 15 June 1984 prepared by TRADOC.

# CURRENT OFFSHORE PETROLEUM DISTRIBUTION SYSTEM

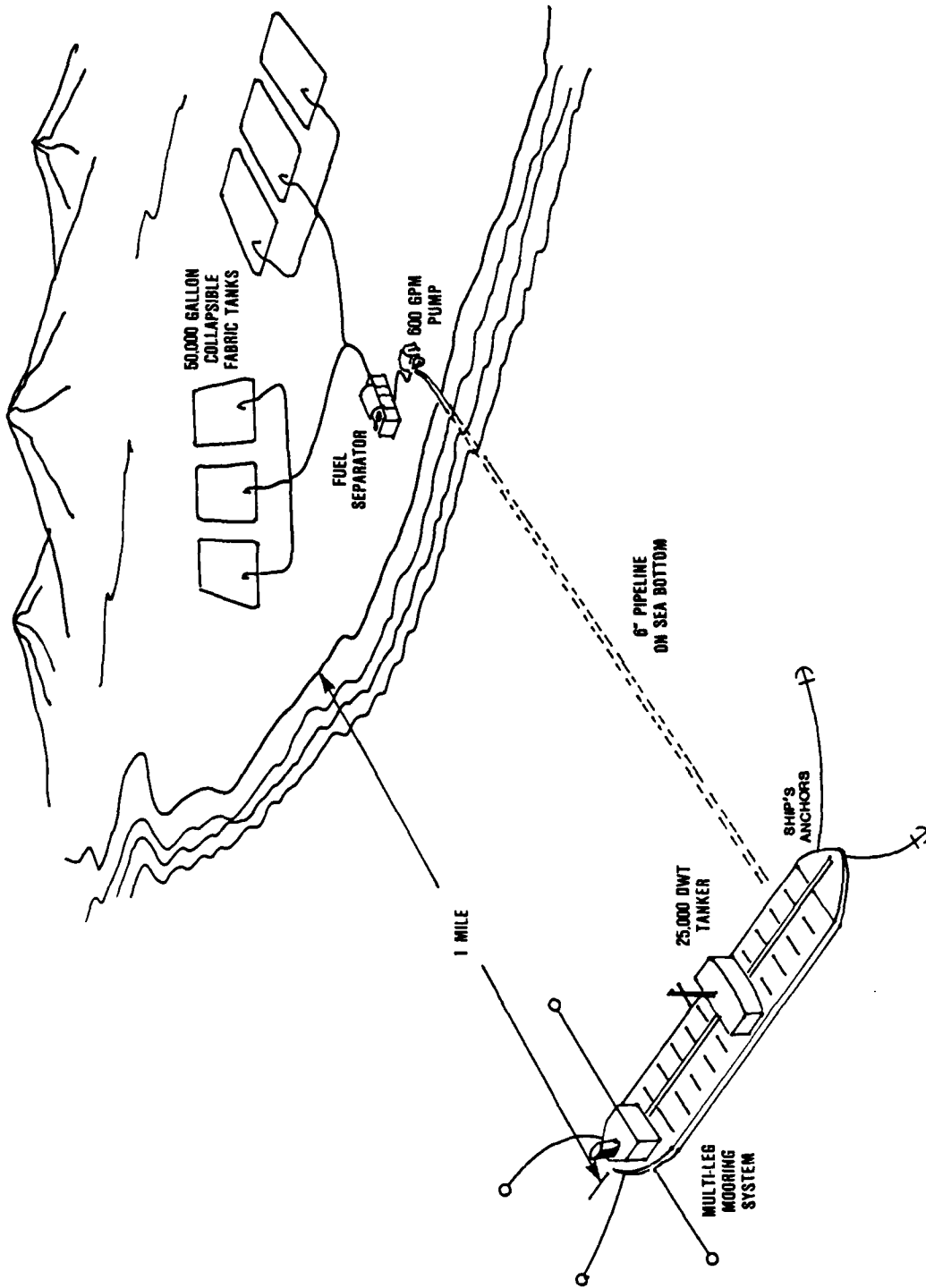


Figure III-2. Current Off-Shore Petroleum Distribution System

## THE BDM CORPORATION

- (3) Study, Bulk Petroleum Fuels Distribution in a Theater of Operations, dated June 1977 prepared by the U.S. Army Logistics Center.
- (4) Science and Technology Objectives Guide (STOG 82/83) prepared by the Deputy Chief of Staff Army for Operations and Planning.
- (5) "State of the Union" assessment of Army logistics by Deputy Chief of Staff Army for Logistics in September 1983.
- (6) Proceedings of Industry/Army-Navy Seminar on Offshore Bulk Liquid Cargo Discharge Operations, Office of the Assistant Secretary of the Navy (Shipbuilding and Logistics), January 1983.
- (7) TROSCOM Logistic R&D Programs (Draft) prepared by Belvoir Research & Development Center, January 1985.
- (8) Analysis of Army Logistics Hardware Requirements, Appendix C, prepared for Belvoir R&D Center, April 1985 by The BDM Corporation.

In addition to the documented sources cited above, informal data concerning the performance and deficiencies noted in the POL operations portion of the JLOTS II throughput test at Fort Story, Virginia were obtained directly from test observers. A final report of this test was not available to the research team during the conduct of this task.

Following is a listing of deficiencies identified by reference to the above source.

## THE BDM CORPORATION

REFERENCE (1): U.S. Army Logistics Center, Combat Service Support Mission Area Analysis, Level II (CSSMAA II), Main Report, 22 April 1983

### Imperative #21

The ability to construct steel bolted storage tanks is not viable due to lengthy erection time, the significant logistical support required, and current, and projected equipment shortfalls.

### Imperative #27

Lack capability to deliver ashore critical weapons and support systems in bare beach contingency operations.

### Supply #a

Current planning methodology and the impact of newly fielded equipment prevents an accurate estimate of fuel required. Considering the long lead time necessary to effect resupply from CONUS and the cost of inventory, a more accurate methodology is required.

### Supply #o

Recurring deficiencies of incorrect accounting impacts upon POL balances, causes stock fund losses, and distorts usage figures which are the basis for supply.

### Supply #z

Petroleum based fuels availability cannot be assured to support the 1990 fighting force.

### Transportation #b

Current tugs and command/control craft are operationally unreliable.

## THE BDM CORPORATION

REFERENCE (2): TRADOC Draft Battlefield Development Plan, Appendix A, "Prioritization of Mission Area Deficiencies, 15 June 1984.

BDP #169 Inability to Support Watercraft Terminal Operations

Current LOTS facilities lack adequate watercraft operations. Army watercraft fleet is overaged, underpowered, logistically unsupportable and cannot meet increased demands of bare beach contingency operations - will cause delays in deployment of supplies into the theater of operations.

BDP #176 Lack Ability to Quickly Determine Requirements, Assess Alternatives and Monitor Resource Flow

Current manual means of gathering and analyzing logistics is too slow, labor intensive and provides only "best guess" estimate.

BDP #191 Inadequate Tracking and Control of Logistic Assets

There is no effective method to rapidly divert mission essential supplies to the user in order to effect timely combat responsiveness to developments on the battlefield.

## THE BDM CORPORATION

REFERENCE (3): Study, U.S. Army Logistics Center, Bulk Petroleum Fuels Distribution in a Theater of Operations, June 1977

### Major Issues (Findings and Recommendations)

(4) Petroleum distribution system in undeveloped theater requires complex planning and installation by military forces. Trained petroleum hoseline units and equipment are not adequate for Army 21 doctrinal needs.

(7) Lack of TOE equipment limits deployability of petroleum (pipeline) units.

(8) Ability of the Army to conduct over-the-beach petroleum resupply operations in a bare base environment is nearly non-existent due to a lack of pipeline inventory.

(10) Lack of bulk flow meters prevents accurate determination of fuel flow at various receipt and distribution points.

(11) Greater emphasis is needed in the materiel process in identifying user needs and translating those needs to requirements documents.

(12) No means currently exists for rapidly determining the deployability readiness of petroleum systems to meet a contingency.

(13) Limited active duty petroleum forces in the Army severely constrains the ability to maintain an adequate training base for petroleum personnel.

# THE BDM CORPORATION

REFERENCE (4): Deputy Chief of Staff Army for Operations and Planning,  
Science and Technology Objectives Guide (STOG), 82/83

## Mission Area 82/83-6 Combat Service Support

### 6.1/16 Fuel Distribution

b. Current materials and equipment unsuitable for arctic environment.

c. Current hoseline/pipeline technology low in mission reliability and operational effectiveness. Costly in personnel resources and time to install.

d. Current collapsible fuel tanks cumbersome to handle, vulnerable to damage, and have limited shelf life.

g. Current handling techniques for liquids require special purpose equipment for POL and water separately causing duplication of equipment and effort.

h. Ability to offload and store tanker cargoes from offshore in LOTS is not adequate.

i. Current hoseline does not meet float/sink requirement.

## Mission Area 82/83-7 Base Support

### 7/4 Strategic Mobility

c. Current equipment and techniques for conducting LOTS with large tonnages of POL from tankers offshore does not meet requirements.



## THE BDM CORPORATION

### 7/7 Efficiency

Present procedures, materials, and management systems for handling bulk fuel are inefficient and require excessive time and funds to install and maintain.

### 7/8 Facilities Protection

Improved design, operational criteria, security systems, and camouflage techniques are needed to protect facilities, troops, materiel and equipment.

### 7/10 Port Construction

Present capabilities for rapid port construction/rehabilitation are not adequate for efficient discharge from POL tankers in fixed ports and LOTS.

## THE BDM CORPORATION

REFERENCE (5): Deputy Chief of Staff Army for Logistics "State of the Union," September 1983

### Section 8- POL DISTRIBUTION

#### a. Worldwide

(1) POL units need greater capability to receive, store, and issue bulk petroleum without increasing assigned personnel.

(3) Productivity of petroleum units needs to be improved.

(4) More rapid, automated pipeline construction is needed.

(7) Training for POL handlers is inadequate.

(14) Alternative fuel usage is needed to reduce petroleum logistic burden.

#### c. Southwest Asia

(1) Improved LOTS capability is needed. (Pipelaying equipment and techniques, mooring systems, and flexible undersea pipeline/hoseline.)

(2) Improved bulk fuel tank assembly is needed.

(3) Improved tactical marine petroleum terminal is needed.

(4) Procurement of POL LOTS equipment is needed to improve capability.

(6) Additional floating storage for war reserves is needed.

#### d. Korea

(3) Multi-leg mooring capability is needed to offload tankers offshore.

## THE BDM CORPORATION

REFERENCE (6): Office of the Assistant Secretary of Navy (Shipbuilding and Logistics), Proceedings of Industry/Army-Navy Seminar on Offshore Bulk Liquid Cargo Discharge Operations, January 1983.

### Tanker Operations Panel

1. The single point mooring buoy may have limited applications in the forward area, and procedures need to be developed for using tankers with a floating hoseline to discharge offshore.

2. Tug-barge combinations need to be identified for use in ferrying and storing POL.

4. A very large crude carrier (VLCC) is needed for offshore POL storage and the transport of heavy lift cargo (on its main deck) to the forward area.

5. The Dracone bladder needs to be tested in conjunction with an underway tanker to determine what protection (between tanker and Dracone) is required for the bladder.

6. The required initial number of POL lines from ship-to-shore should be minimized by considering JP-5 as a temporary substitute for both diesel and jet fuel.

7. The use of on-site worldwide fuel transfer assets including tugs, barges, and offshore (oil field) service and supply vessels need to be considered by the military services.

# THE BDM CORPORATION

## Ship Mooring Buoy Panel

1. Conventional multi-leg moors for tankers may be used only where winds, currents, and waves are predominantly in one direction.

2. The Navy Single Point Mooring (SPM) system for tankers needs to be developed for use where winds, currents, and waves occur under changing, multi-directional conditions.

3. Other Single Point Mooring system concepts (i.e., Catenary Anchor Leg Moor (CALM), Single Anchor Leg Moor (SALM), Prefabricated Oil Unloading Dolphin (PROUD), and Articulated Loading Platform (ALP) need to be studied and operationally evaluated.

5. An up-to-date inventory and status of U.S. owned/controlled industry buoys, both ashore and afloat, should be maintained in peacetime by the government to permit their possible use in contingency operations.

6. Installation procedures and component requirements for all single point mooring systems need to be simplified.

## Ship-to-Shore Transfer Systems Panel

1. Pre-positioning of ship-to-shore POL transfer systems is essential and should be further evaluated.

2. Commercial vessel use should be maximized to transport POL and ship-to-shore POL transfer systems.

5. More trade-off studies are needed between various ship-to-shore POL transfer systems and equipments.

6. A full-scale ship-to-shore POL transfer test is needed to evaluate current existing capability and to evaluate various state-of-the-art transfer system.

# THE BDM CORPORATION

REFERENCE (7): TROSCOM LOG R&D Programs, (Draft), BRDC, January 1985

#3 (Log Center Priority #8) Pipeline, Bulk Liquid, Ship-to-Shore

The Army cannot meet JCS guidance in message DTG 041939Z, April 1983, providing the required capability for mooring system in Southwest Asia.

	<u>Handle DWT</u>	<u>Offshore Distance</u>	<u>BBLS/Day</u>
<u>Requirement:</u>	40,000	4 mi	30,000
<u>Capability:</u>	25,000	1 mi	17,000

#13 (Log Center Priority #21) Extend Shelf and Service Life of Collapsible Tanks

Army lacks durable collapsible tank that can handle fuel or water under all climatic conditions. Tank specifications and laboratory test methods currently being used can only assure troops that tanks have a five-year shelf life and one-year service life. There is a need for test methods to determine when tanks in storage or use should be discarded, to prevent premature disposal of tanks and to reduce excessive inventory of different size fabric tanks.

#18 (Log Center Priority #75) Polyethylene/Composite Materials, Petroleum Piping

Current petroleum pipeline systems require considerable effort to install and maintain. Polyethylene or other composite material for pipe may be the opportunity to achieve Army pipeline objectives and reduce the effort required for installation and maintenance.

## THE BDM CORPORATION

### #20 (Log Center Priority #77) Hasty Constructed Large Capacity Fuel Storage Tanks

These tanks will provide an alternative to the use of fabric tanks which are limited in capacity and are highly vulnerable. Fuel logistics of the modern Army require large volume storage with improved survivability expectations. Present system is labor intensive and is virtually unprotected.

### #23 Tactical Petroleum Terminal (TPT)

Current storage and distribution system is labor intensive requiring a great amount of time to construct.

### #24 Ship-to-Shore Pipeline/Mooring Concepts

The general requirements for mooring and sea-state condition are not well defined. This effort will identify various design options for off-loading tankers under various operational and geographical conditions.

Current Army tanker offshore pipeline facility cannot decrease tanker unloading time, thereby increasing tanker vulnerability.

### #26 Multi-Leg Mooring System

No adequate provision exists for a mooring system for off-loading tankers up to 25,000 DWT in primitive areas where no other off-loading facilities of any type are available. Army lacks the capability of quickly establishing a marine terminal in an unimproved area that would assure adequate fuel supply for troop operation in this environment.

## THE BDM CORPORATION

### #27 Gravitational Mooring System (GMS)

The present mooring capability is limited to a 25,000 DWT tanker under a sea-state two and two knot currents. Army lacks a mooring system that is rapidly installable in a bare base environment.

	<u>Handle DWT</u>	<u>Sea-State</u>	<u>Current</u>
<u>Requirement:</u>	70,000	4	4 Knots
<u>Capability:</u>	25,000	2	2 Knots

### #28 Propellant Embedded Anchor Mooring System (PEAMS)

Army lacks a tanker mooring facility which is rapidly installable in a bare base environment.

	<u>Handle DWT</u>	<u>Sea-State</u>	<u>Current</u>
<u>Requirement:</u>	40,000	4	4 Knots
<u>Capability:</u>	25,000	2	2 Knots

## THE BDM CORPORATION

REFERENCE (8): Analysis of Army Logistics Hardware Requirements, Appendix C, prepared for Belvoir R&D Center, April 1985 by The BDM Corporation.

Deficiencies identified in this source are presented in Figure III-3.



# POL LOGISTICS SYSTEM--ARMY 86

	REFINERY	TANK FARM	PORT	PORT	PORT	THEATER SUPPORT AREA	CORPS SUPPORT AREA	DIVISION SUPPORT AREA	BRIGADE BATTALION TRAINS	UNIT
CURRENT LOGISTICS SYSTEM COMPONENTS										
PROBLEMS			<ul style="list-style-type: none"> <li>INTERDICTION VULNERABILITY</li> <li>RISK IN MOVING TANKS AND TANKS FERRING FUEL IN ROUGH SEAS</li> <li>INABILITY TO TRANSFER FUEL TO SHORE FROM LONG STAGNOF DIS TANCES IN SHAL LOW WATER</li> <li>LACK OF RAIL FACILITIES IN UNDEVELOPED THEATER</li> </ul>		<ul style="list-style-type: none"> <li>INTERDICTION VULNERABILITY</li> <li>PIPELINE DIS THRUPTION SLOW TO INSTALL AND LAJOR INTENSIVE</li> <li>HEAVY LOGISTIC BURDEN WITH PIPELINES</li> <li>INABILITY TO MOVE ADEQUATE AMOUNTS OF FUEL THROUGH PIPE LINES/HOSELINES</li> </ul>	<ul style="list-style-type: none"> <li>INTERDICTION VULNERABILITY</li> <li>FIELD STORAGE CAPABILITY IS VULNERABLE TO DAMAGE AND LAJOR INTENSIVE TO IN STALL</li> <li>HEAVY LOGISTIC BURDEN WITH HOSELINES/STOM AGE TANKS</li> </ul>	<ul style="list-style-type: none"> <li>FIELD STORAGE SYSTEM NOT SUFFICIENTLY MOBILE</li> </ul>	<ul style="list-style-type: none"> <li>INABILITY TO DETERMINE AND MAINTAIN FUEL QUALITY</li> <li>INABILITY TO INADEQUATELY DISTRIBUTE FUEL IN ARCTIC</li> <li>THREAT ATTACK VULNERABILITY</li> </ul>	<ul style="list-style-type: none"> <li>HEAVY POL LOGIS TIC DEMANDS</li> <li>INTERDICTION VULNERABILITY</li> <li>HIGH RISK TO PERSONNEL IN FORWARD BATTLE AREA REFUELING</li> </ul>	<ul style="list-style-type: none"> <li>FINE RESISTANT FUELS NEEDED TO REDUCE RISK</li> <li>ALTERNATE AND MULTI-PURPOSE FUELS NEEDED</li> <li>INABILITY TO SERVICE COMBAT VEHICLES SAFELY AT BATTLE STATIONS</li> </ul>

Figure III-3. Current System Deficiencies

C. DEFICIENCY SUMMARY

The Army's Tactical Marine Petroleum Terminal provides a limited capability to deliver bulk fuel over-the-shore in certain theaters under selected environmental and geographical conditions. However, newly evolving requirements and tactical situations have led to a need for a more capable and reliable system. Improvements have been made to various parts of the system over a period of several years, and recently extensive effort has been directed toward the problem.

Deficiencies in the U.S. Army's capability to deliver fuel in bulk to an undeveloped theater are grouped in three categories for ease in formulating alternative solutions and concepts later in the report. The three categories are:

- (1) Off-shore mooring systems
- (2) ship-to-shore transport systems, and
- (3) on-shore fuel storage systems

The deficiencies have been summarized according to the above categories and are presented in Figures III-4, III-5, and III-6.

# **MOORING SYSTEM DEFICIENCIES**

## **(COMPONENTS OF MULTI-LEG MOORING SYSTEM AND TACTICAL MARINE TERMINAL)**

- CANNOT HANDLE LARGE MODERN TANKERS
- DOES NOT MEET WORLDWIDE REQUIREMENTS AS TO ENVIRONMENTAL AND SEA BED CONDITIONS AND IS NOT RAPIDLY INSTALLABLE
- IS MANPOWER INTENSIVE TO EMLACE AND RECOVER

Figure III-4. Inability to Maintain Secure Position for Off-Shore Mooring Facility

# **SHIP-TO-SHORE PIPELINE/HOSELINE DEFICIENCIES**

## **(COMPONENTS OF MULTI-LEG MOORING SYSTEM AND TACTICAL MARINE TERMINAL)**

- CANNOT MAINTAIN NEEDED QUANTITY AND PRESSURE OVER EXTENDED DISTANCES
- REQUIRES EXCESSIVE TIME AND MANPOWER FOR INSTALLATION AND MAINTENANCE
- CURRENT INSTALLATION METHOD PHYSICALLY LIMITS LAYING PIPELINE OVER EXTENDED DISTANCES

Figure III-5. Ship-To-Shore Fuel Transport Systems Deficiencies

## FUEL STORAGE DEFICIENCIES

- STEEL STORAGE TANKS NOT RAPIDLY DEPLOYABLE FOR FUTURE ARMY MOBILITY
- STEEL STORAGE TANKS CONSTRUCTION LABOR INTENSIVE AND TIME CONSUMING
- COLLAPSIBLE STORAGE TANKS SERVICE LIFE LIMITED FOR LOTS TERRAIN AND HANDLING
- FABRIC STORAGE TANKS EXCESSIVELY VULNERABLE TO ENEMY ACTION
- COLLAPSIBLE STORAGE TANKS ARE BULKY, CUMBERSOME AND REQUIRE SPECIAL HANDLING EQUIPMENT
- INABILITY TO RAPIDLY TRACK AND CONTROL BATCH INTERFACE FUEL STORAGE

Figure III-6. Inadequate On-Shore Fuel Storage Systems

CHAPTER IV  
NEAR-TERM PROGRAMMED IMPROVEMENTS

A. GENERAL

As a result of needs identified, principally with rapid deployment concepts and theaters of operation associated with near term contingencies, certain specific initiatives have been taken to upgrade the Army over-the-shore bulk fuel delivery capability. These initiatives will result in procurement actions for state-of-the-art materiel which are intended to satisfy near to mid-term requirements. These programmed improvements were generated as a result of the Southwest Asia Petroleum Distribution System Operational Project (SWAPDOP).

Since July 1983, to provide a near term petroleum distribution capability for Southwest Asia, a series of Action Officer Workshops (AOW) has convened periodically. AOW efforts have increasingly focused on those issues pertaining to early procurement of offshore mooring and pipeline systems for a specific area of operations. One issue that has emerged during the course of the AOW is one of doctrine regarding Army and Navy responsibilities for offshore petroleum discharge systems. A duplication of mission is considered to exist in that each Service has the responsibility to provide offshore petroleum discharge systems in support of logistics over the shore. The Navy is tasked to install, operate and maintain a system in support of Marine forces. The Army, as part of its inland petroleum distribution mission to support all Services in the theater must install, operate and maintain offshore systems. A consensus exists within the AOW that one Service should be charged with the mission in the interest of cost effectiveness/efficiency. Although it is recognized by the AOW that this issue may not be resolved in the near term, it needs to be addressed. Pending resolution of the issue the AOW determined that the Navy lead would be followed on the offshore petroleum discharge system (OPDS) consisting of the single anchor leg mooring (SALM) and four mile pipeline described in the following paragraphs. The

## THE BDM CORPORATION

The propellant embedded anchor mooring system (PEAMS) and one mile ship to shore pipeline, described in subsequent paragraphs, will continue to be managed and procured by the Army with the assistance of a joint Army/Navy design group.

### B. MOORING SYSTEMS

Two mooring systems will be acquired. The first, a propellant embedded anchor mooring system (PEAMS) will have the following principal characteristics:

(1) Provide capabilities to moor vessels up to 40,000 deadweight tons in depths from 15 ft to 120 ft in a sea-state 4 condition with a current of four knots within 10 degrees of the longitudinal axis of the tanker and a 30-knot wind abeam.

(2) Be capable of being installed within 72 hours after arrival at the site with one construction platoon working in two 12-hour shifts. The anchors need not be recoverable.

(3) Be capable of being installed in sea-state 2 with 1.5 knot current at depths from 15 feet up to 120 feet in sand, mud, and clay, excluding rock.

(4) Have a service life of at least one year and a shelf life of at least 20 years.

(5) Be capable of surviving sea-state 7, wave height of 30 ft, current of 4 knots, winds of up to 55 knots, and a 10 ft tide without tanker being hooked up.

The system is similar in design and function to the multi-leg mooring system currently being employed by the Army but will be capable of improved operating limits.

## THE BDM CORPORATION

The second system being acquired is the single anchor leg mooring system (SALM), which will have the following principal characteristics:

(1) Be capable of being transported on board and/or towed by a surface water vessel to and from the deployment site, and must be recoverable.

(2) Provide, at a minimum, capabilities to moor a 70,000 deadweight ton tanker in a sea state 5 condition with a current of four knots.

(3) Be capable of providing 1000 gallons per minute of bulk liquid thru its manifold.

(4) Be capable of being installed within 72 hours by not more than 8 personnel per 12 hour shift of the Engineer Port Construction Company using required support from the equipment and diving section of the company and required support vessels for positioning.

(5) Include all adapters/reducers/valves and hoses for connection to standard military sealift command (MSC), commercial tankers, and ship-to-shore pipeline.

(6) Be capable of being installed in sea state 3 with 1 1/2 knot current at depths up to 120 feet.

(7) Have a service life of at least five years and a shelf life of at least 20 years.

(8) Be capable of surviving sea-state 7, wave height 30 ft, current of 4 knots, winds of 55 knots, and a 10-foot tide without tanker hook-up.

The mooring system is a floating platform that is towed to the area of employment by a tanker or ocean-going tug. It may also be transported to the area of employment by resting in a cradle on the deck of the tanker. A sub-bottom profiler, side-scan sonar, and diving personnel are used to position the platform. The platform is then sunk by flooding the aft and forward ballast tanks causing the platform to rest on the ocean floor. The system includes sufficient flexible pipe to tie into the ship-to-shore pipeline and approximately 600-800 feet of tanker hose. The platform is recoverable by blowing air into the ballast tanks thereby refloating the platform. The SALM is illustrated in Figure IV-1.



## SINGLE ANCHOR LEG MOORING (SALM)

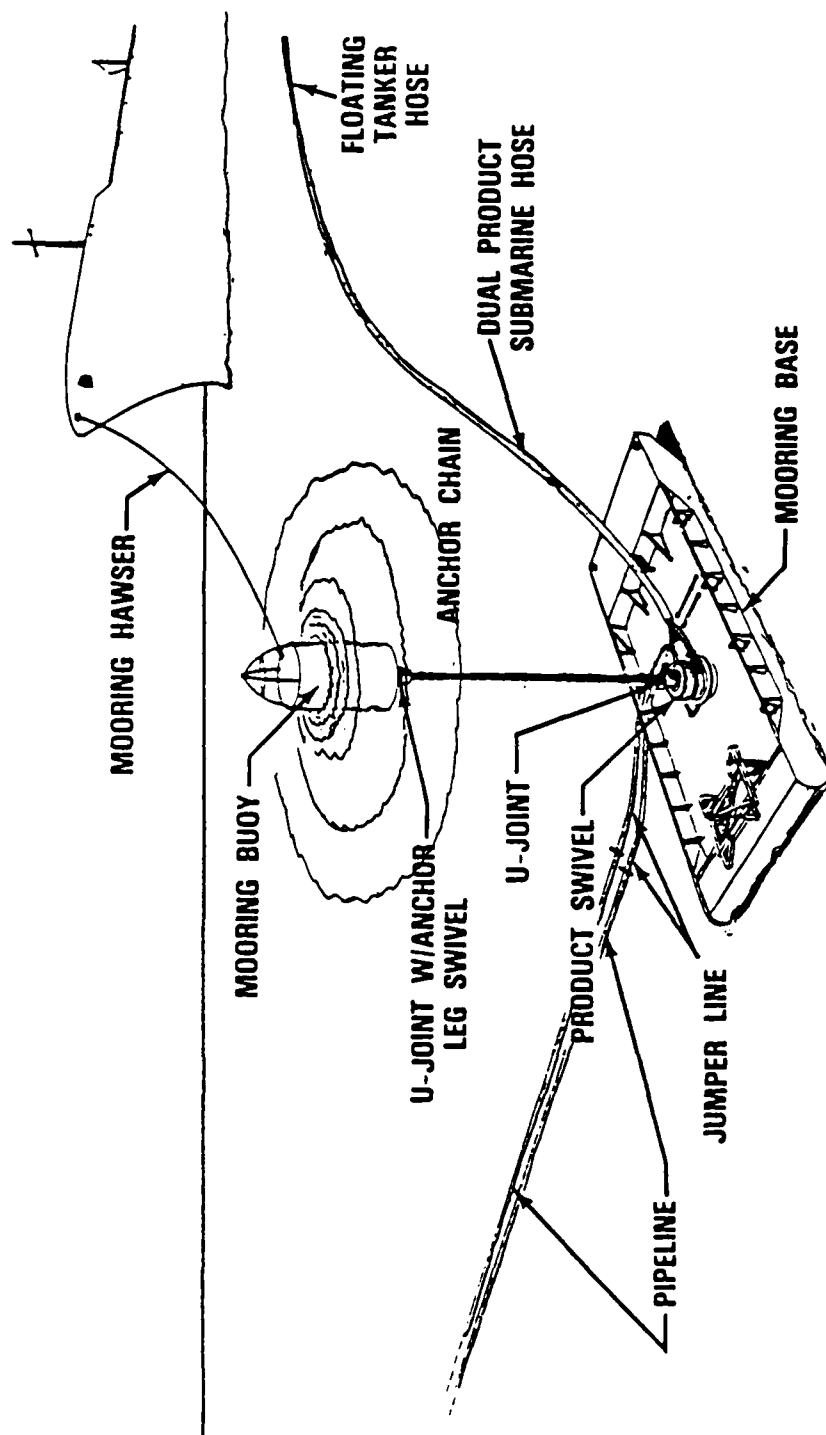


Figure IV-1. Single Anchor Leg Mooring

## THE BDM CORPORATION

### C. PIPELINE SYSTEMS

Current contingency plans require quickly installed pipelines to transport larger volumes (30,000 barrels per day) of bulk liquid from ship-to-shore.

Two bulk liquid ship-to-shore pipelines will be acquired; a one statute mile system and a four statute mile system. The pipeline(s) will replace the current multi-leg mooring system. Both systems will have the following principal characteristics.

(1) Be capable of being installed within 72 hours providing at least 600 gpm at a distance of one mile off shore.

(2) Consist of one or more lines capable of providing 400 gpm within 72 hours, 800 gpm within 144 hours, and 1200 gpm within 216 hours at a distance of four miles off shore.

(3) Be capable of operating at depths up to 120 feet and be provided with anchoring devices to preclude movement if required.

(4) Be repairable by typically trained personnel of minor leaks, holes and splits within 6 hours under emergency conditions (high volume demand) and depths up to 120 feet.

(5) Have a service life of at least one year, and a shelf life of at least 20 years.

(6) Transport bulk petroleum products and be recoverable.

(7) Include all adapters/reducers/valves and hoses for connection to selected mooring systems, standard Military Sealift Command (MSC) vessels, commercial tankers and on-shore Tactical Petroleum Terminal or terminals.

### D. ON-SHORE STORAGE

On-shore storage will be accomplished by the use of a tactical petroleum terminal (TPT) which will consist of the equipment necessary to receive, store, and issue multi-product bulk petroleum in an over-the-shore operation. The TPT will be composed of pumps, hoses, and collapsible fabric tanks with a receipt and storage capability of

3,600,000 gallons. Nine 400,000 gallon fuel tank modules will utilize 50,000 gallon collapsible fabric tanks or 5000 barrel bulk fuel tank assemblies (BFTA). As described earlier, the BFTA is a large volume, self-supporting, rapidly deployable, collapsible bulk fuel tank. The TPT when used with the one mile pipeline will have a throughput capacity of 600 gpm over the shore. When used with the four mile pipeline it will have a capacity of 1200 gpm. The complete TPT will be capable of being made operational within 72 hours and recovered within 72 hours.

E. SUMMARY

Figure IV-2 presents a summary of the near term future system for bulk fuels handling over the shore in an undeveloped theater. Systems have been grouped into the same three categories as for current systems described earlier. Two types of mooring systems are planned; one using propellant embedment anchors (PEAMS), and a second using a gravitational mooring system (GMS). The gravitational mooring system employs the single anchor leg mooring (SALM) portrayed in Figure IV-1. Ship-to-shore transport of bulk petroleum products will be by pipeline. A one mile pipeline will generally be used with the PEAMS where appropriate standoff distances and environmental conditions exist. A four mile pipeline will generally be used with the SALM where tanker standoff distances are greater than one mile. The pipe for the four mile pipeline will be a 6 inch flexible pipe. The pipe for the one mile pipeline may be the same 6 inch flexible pipe or threaded steel pipe sections. On-shore storage will use 5,000 barrel BFTA tanks supplemented with 50,000 gallon tanks where BFTA stocks may be limited.

NEAR TERM FUEL DELIVERY SYSTEM

- TANKER MOORING FACILITIES
  - PROPELLANT EMBEDDED ANCHOR MOORING SYSTEM
    - PROPELLANT EMBEDMENT ANCHORS
    - ASSOCIATED LAUNCHING AND RECOVERY EQUIPMENT
  - GRAVITATIONAL MOORING SYSTEM (GMS)
    - SINKABLE PLATFORM
    - ASSOCIATED INSTALLATION AND HOOK-UP EQUIPMENT
- SHIP-TO-SHORE TRANSPORT
  - ONE MILE PIPELINE
  - ASSOCIATED INSTALLATION EQUIPMENT
  - FOUR MILE PIPELINE
  - ASSOCIATED INSTALLATION EQUIPMENT
- ONSHORE STORAGE
  - 50,000 GALLON COLLAPSIBLE STORAGE TANKS
    - OR
  - 5,000 BARREL BULK FUEL TANK ASSEMBLIES (BFTA)
  - ASSOCIATED PUMPS, FILTERS, DISTRIBUTION/DISPENSING ASSEMBLIES
  - ASSOCIATED INSTALLATION EQUIPMENT (STANDARD MILITARY ENGINEERING ITEMS)

CAPABILITIES - 40,000 TO 70,000 DWT TANKERS, SEA-STATE 4, 4 KNOTS CURRENT, 4 MILES FROM SHORE, 1,440,000 GALLONS THROUGHPUT IN 20 HOURS, 3.6 MILLION GALLONS STORAGE (34,000 BARRELS THROUGHPUT, 85,700 BARRELS STORAGE)

Figure IV-2. Near-Term Future System

A representative near term off-shore petroleum distribution system as it will be employed is illustrated in Figure IV-3. The figure shows a tanker moored with the SALM. The SALM rests on the sea bottom with a buoy rising to the surface to which the tanker is moored. A 6 inch flexible pipeline is used for ship-to-shore transport of the bulk petroleum since tanker standoff distance may be up to 4 miles. Prior to deployment, the flexible pipe will be stored on reels on the deck of the supply tanker. A pumping station using a 600 gpm pump and fuel separator are at the shoreline to distribute fuel coming ashore to a series of tank modules made up of 5000 barrel BFTA tanks. Additional pipelines may be added to achieve the full capability of the system.

Although near term development and acquisition programs improve the Army's capability measurably, it is premature to assess the ability of the near term system to solve completely all of the deficiencies now existing. For one reason, the current development programs are tailored to a particular world region where environmental conditions are not totally representative of all regions of potential conflict. Variations in off-shore bottom gradient, wind force and direction, tidal ranges, sea bottom geology, exposure of the shoreline to swell conditions, off-shore reefs and other factors will introduce different demands in mooring systems, ship-to-shore transport, and on-shore storage, than those being addressed in the near term. For example, conflict in the Arctic is not without reason, yet the system that is being designed for the near term probably will not function as required under arctic conditions due to pack ice movement, ice scouring of the bottom, hostile coastlines, and extremely steep off-shore bottom gradients.

## NEAR TERM OFFSHORE PETROLEUM DISTRIBUTION SYSTEM

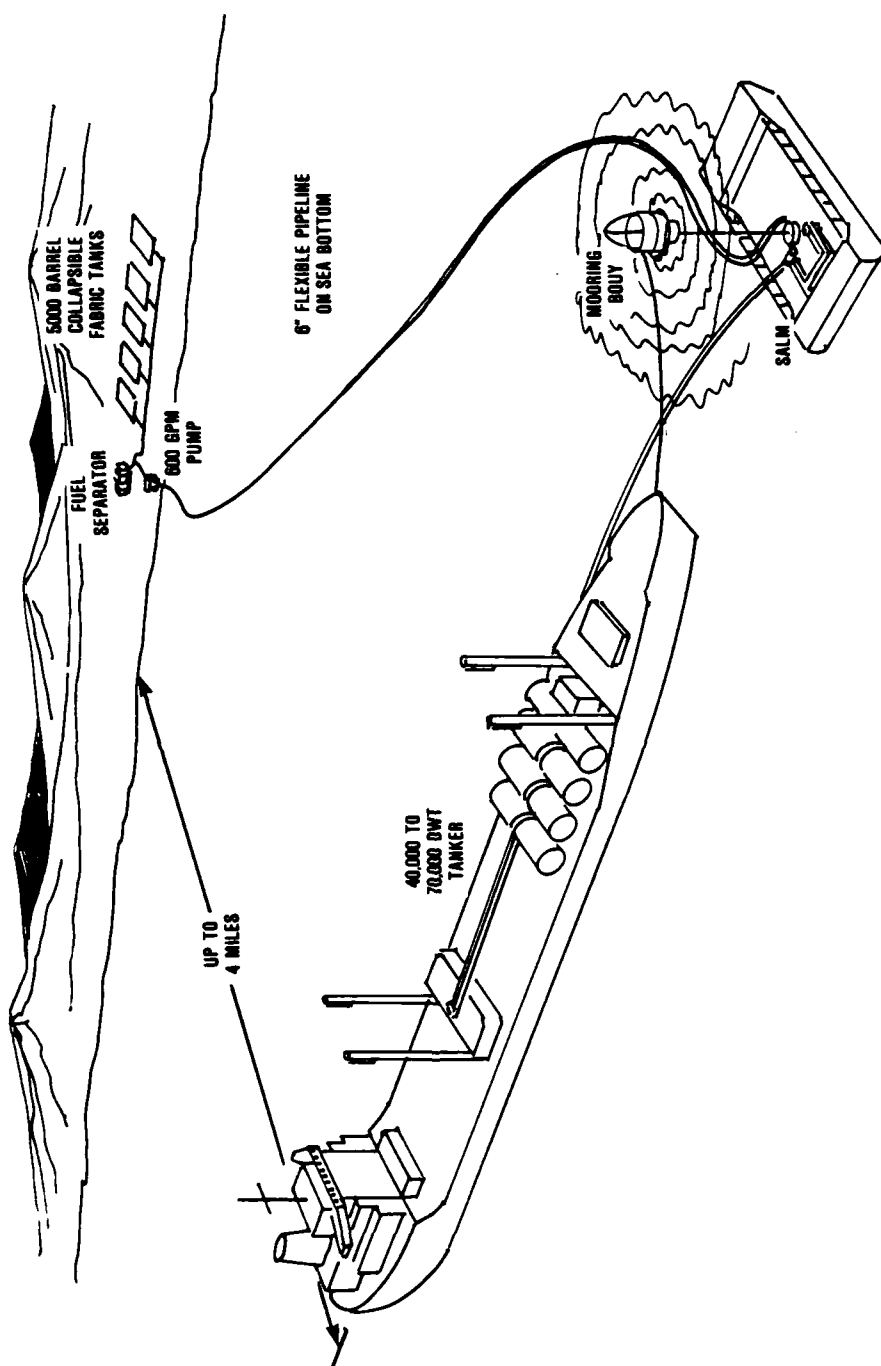


Figure IV-3. Near-Term Off-Shore Petroleum Distribution System

CHAPTER V  
LONG-TERM NEEDS

A. FUELING SUPPORT FOR ARMY 21

1. General

Army 21 logistic support is centrally directed, austere, and limited to combat essentials. Logistics units for Army 21 operate throughout the AirLand Force (ALF) area of operations which is illustrated in Figure V-1. Although logistic support, including fueling support, is centrally managed, execution is decentralized. The sustaining base support area (SBSA) encompasses the port, or LOTS area, through which supplies enter the theater. The SBSA is an extension of the CONUS production base and may be in the theater or offshore. The sustaining base is responsible for the central management and control of all logistic operations required to support the AirLand Force. To support a fast moving combat environment, supply activities are mobile and dispersed throughout the area. Supplies are automatically push-shipped forward based on predicted demand generated by the regimental support force (RSF). The RSF is organic to the regiment and functions as the logistics operator and management center for the regiment. RSF elements provide supply down to the maneuver element.

The integrating activity responsible for the logistics planning, management, and reconstitution of the maneuver regiment is the AirLand Force Support Command (ALFSCOM). Each area of operations within the Airland Force Support Area (ALFSA) has a separate ALFSCOM. A logistics management center (LMC) and movements control center (MCC) are co-located within each ALFSCOM. The ALFSCOM is internally task organized to provide complete logistic support, including fueling, to Army and other Service components assigned to the ALF. Within the boundaries of the ALF area of operations, land battle forces (LBF) are located. The LBF is a division-size force. Three regimental close combat forces (CCF) operate within a designated LBF area, with each CCF supported by a RSF. These combat

# ARMY 21 THEATER OF OPERATIONS

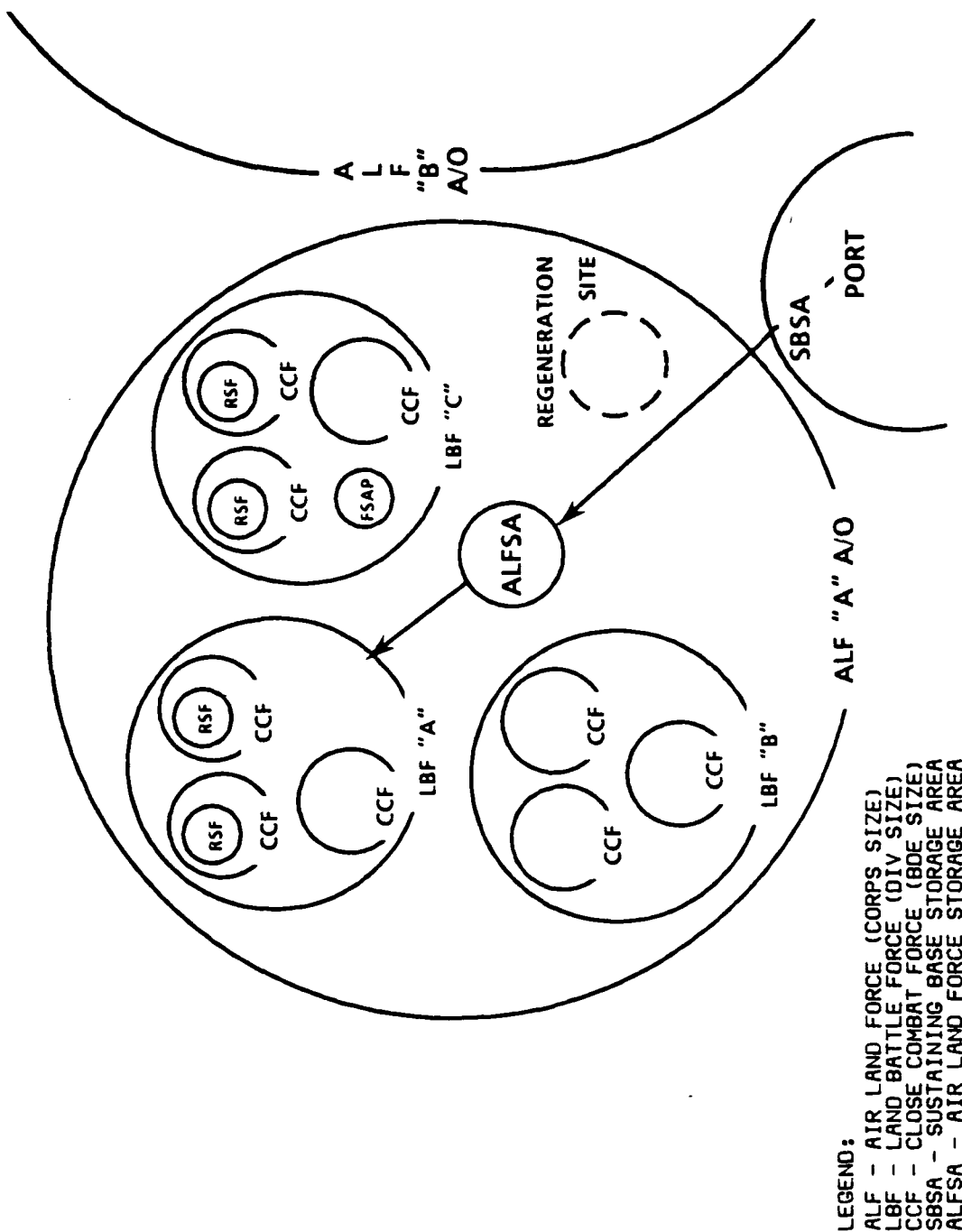


Figure V-1. Army 21 Doctrinal Theater Layout



## THE BDM CORPORATION

forces are comparable in size to the brigades of Army 86. Each maneuver element within the regiment is supported by a forward support unit comprised of RSF elements.

Sustainment of unit combat effectiveness for Army 21 operations is accomplished through reconstitution operations in the ALF. Reconstitution is comprised of two distinct operations: replenishment and regeneration. Replenishment is the process of sustaining readiness and operational capabilities through continuous, uninterrupted support to the regiment; thus, in general, it is the only part of reconstitution which involves fueling support.

### 2. Fueling Support Operations

Figure V-2 shows the nodes and links in the fueling support chain as conceptualized for Army 21 from the receiving port to the maneuver elements. The port is located within the sustaining base support area (SBSA) and may be characterized by an established port with fully constituted facilities for receiving and transmitting large volumes of fuel in bulk. At the other end of the spectrum, the port may consist of an over-the-shore delivery system in an undeveloped theater where all components of the system; offshore discharge, ship-to-shore pipeline, on-shore storage, and distribution/issue facilities, must be introduced to the theater and installed. It is this situation, which represents a worst case scenario, that we are mainly concerned with in this study.

The SBSA serves mainly as a conduit through which supplies are throughput to the ALF area and forward support activities. RSF and forward support units are task organized to insure resupply forward to combat forces. Units are not required to come off the line for resupply. Emphasis in Army 21 on preconfigured unit loads will have a significant impact on handling packaged POL products but is not expected to have any great effect on bulk POL. Nevertheless, the delivery of appropriate fuel types (e.g., diesel, mogas, JP) in the required amounts to satisfy user needs will call for a highly responsive system.

Several important changes in fueling support for Army 21 versus the current system (Army 86) can be anticipated. Among these changes are the following:

# ARMY 21 FUELING SUPPORT

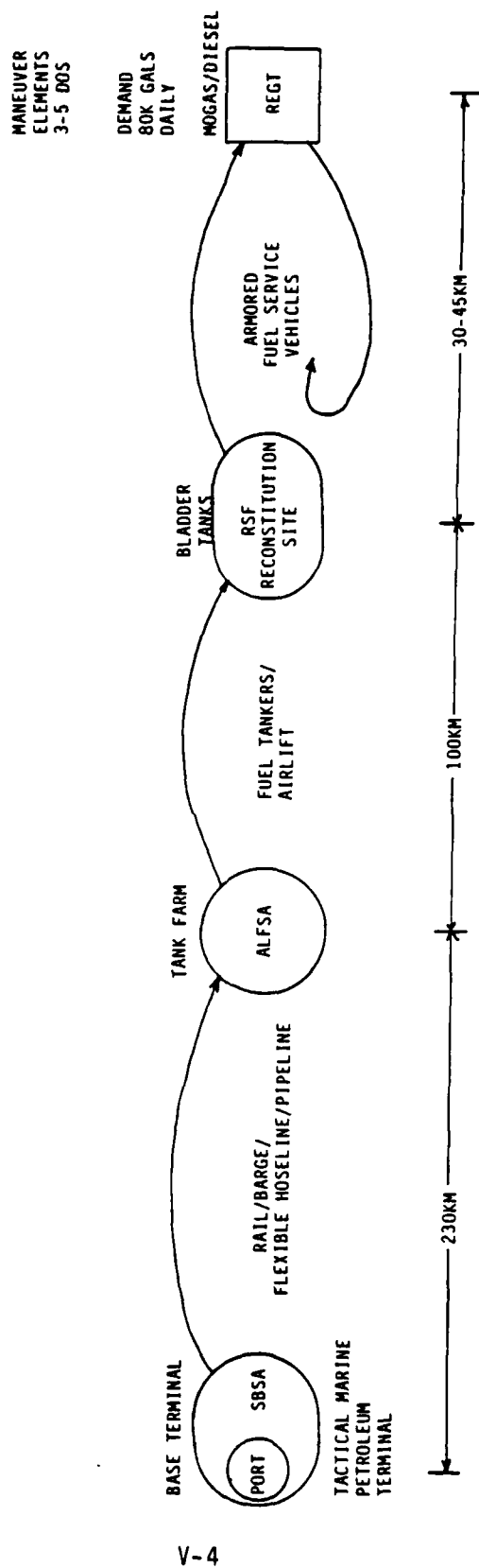


Figure V-2. Fueling Support Chain for Army 21

## THE BDM CORPORATION

● **Greater volume of fuel required.** The increased tempo of operations together with a more highly motorized ground fleet, is expected to increase the daily consumption of petroleum products by Army 21 maneuver elements. Current contingency plans call for up to 30,000 barrels per day of petroleum liquid to be transported from ship-to-shore in the near term, but this may increase to something like 40,000 barrels per day. As a result:

- Larger sea-going tankers will be employed.
- Larger tankers will have greater draft, thus requiring deeper waters for maneuvering and mooring, and greater standoff distances for delivery of their cargo.
- Larger tankers will have greater deadweight tonnages which will impose heavier loads on mooring systems.
- Larger ships will present more attractive targets for enemy attack and will result in greater cargo loss should ship be lost to enemy action or other serious casualty.

● **Greater storage capacity will be needed in the vicinity of the sea-shore interface.** Despite the higher number of days of supply held by maneuver elements in the Army 21 concept, it will not be practical to maintain large tank farms as far forward as is currently the practice due to the high mobility of forces and greater diversification of battle zones. Although greater storage capacity is expected to be needed, dispersal of logistic support areas may modify the concentration of fuel storage in a single tank farm. Some factors related to increased storage capacity are:

- Larger individual tanks will permit installation and recovery in a shorter period of time.
- Storage nearer the port or shoreline should be less vulnerable to enemy attack.
- Off-shore storage in tankers, barges, or collapsible floating bags; or subsea storage, might provide a greater storage capability sooner, and less vulnerable than on-shore storage.

## THE BDM CORPORATION

- **Greater tanker standoff distances will require better pipe laying capability.** In some parts of the world, standoff distances from shore for supply tankers may be several miles or more due to environmental conditions. Vulnerability to attack may also make greater standoff from the shoreline desirable.

- Pipelines must be capable of being deployed under more severe weather and sea conditions.

- Pipeline installation and maintenance must be accomplished with fewer dedicated personnel.

- **Higher performance pumping and pipeline systems will be needed to achieve higher flow rates and pressures.** Increased standoff distances and greater amounts of fuel to be transferred would result in unacceptable turnaround times for the supply tankers if fuel were transferred at flow rates currently experienced with present-day systems. Friction and head losses would reduce the flow rate and pressure drastically with greater pumping distances and the time required to offload a modern seagoing supply tanker would be excessive without using a series of booster pumping stations. Larger pipeline and higher capacity pumps, at the point of origination off-shore, would increase the rate of flow and, thus, speed tanker turnaround time. A flow rate of 5000 gallons per minute has been established by the U.S. Navy in Operational Requirement OR-YAW13 for their Offshore Bulk Fuel System (OBFS). Insufficient throughput can be improved by increasing the size of the pipe and the pump capacity. These changes, however, may be difficult. Larger size pipe introduces higher cost, new handling technologies and equipment, special personnel skills, and greater logistic burden. Increased pump capacity means larger pumps and prime movers, increased equipment complexity and probably increased maintenance. On-shore storage installation will not be any more rapid than with the current system although the near term system will provide increased storage capacity.

## THE BDM CORPORATION

• Vulnerability of fixed-location operations in the future will be greater than at present due to new longer range weapon systems. Survivability of forces and support facilities will be an acute problem in the Army 21 concept of operations. An operation in which a large tanker remains moored in the same location for several days to transfer fuel to shore for storage is clearly at high risk from enemy attack. Without a completely secure area and extensive protection from attack, the survivability of an extended off-shore fuel transfer operation is very doubtful. This is particularly true when the system is planned to be operational within 72 hours of the initial landing. Furthermore, due to the quantities of fuel required, it will be necessary that one tanker be replaced almost immediately by another for a virtually continuous operation at the same mooring. As a result of increased vulnerability, greater dispersal of amphibious operating areas (AOA) where over-the-shore operations are dictated by tactical operations or a lack of developed port facilities, will be a significant factor associated with Army 21 operations. Army 21 over-the-beach concepts call for multiple landings during the initial period (one to three days) of an operation to include logistical support over those beaches. The use of multiple, dispersed beach heads is opposed to expansive logistical support areas employed in World War II, will be needed for quick strike operations. A massive on-shore infrastructure may, in fact, be undesirable since it will not contribute effectively to the highly mobile force deployments of the Army 21 concept.

Figure V-3 illustrates the dispersal of beach heads using concealment techniques and decoy operations. Multiple beach heads will require logistic support to each of the beach heads. This may, in fact, call for the use of smaller tankers or barges to support each beach head or the tanker moving successively from one beach head to the next to provide the necessary POL. Mooring and ship-to-shore transport facilities with pumps and hoses/pipelines will be needed to serve each beach head. Standoff distances may still be greater than present contingency plans provide for depending upon the geography of the area.

# FUTURE OFFSHORE PETROLEUM DISTRIBUTION SYSTEM

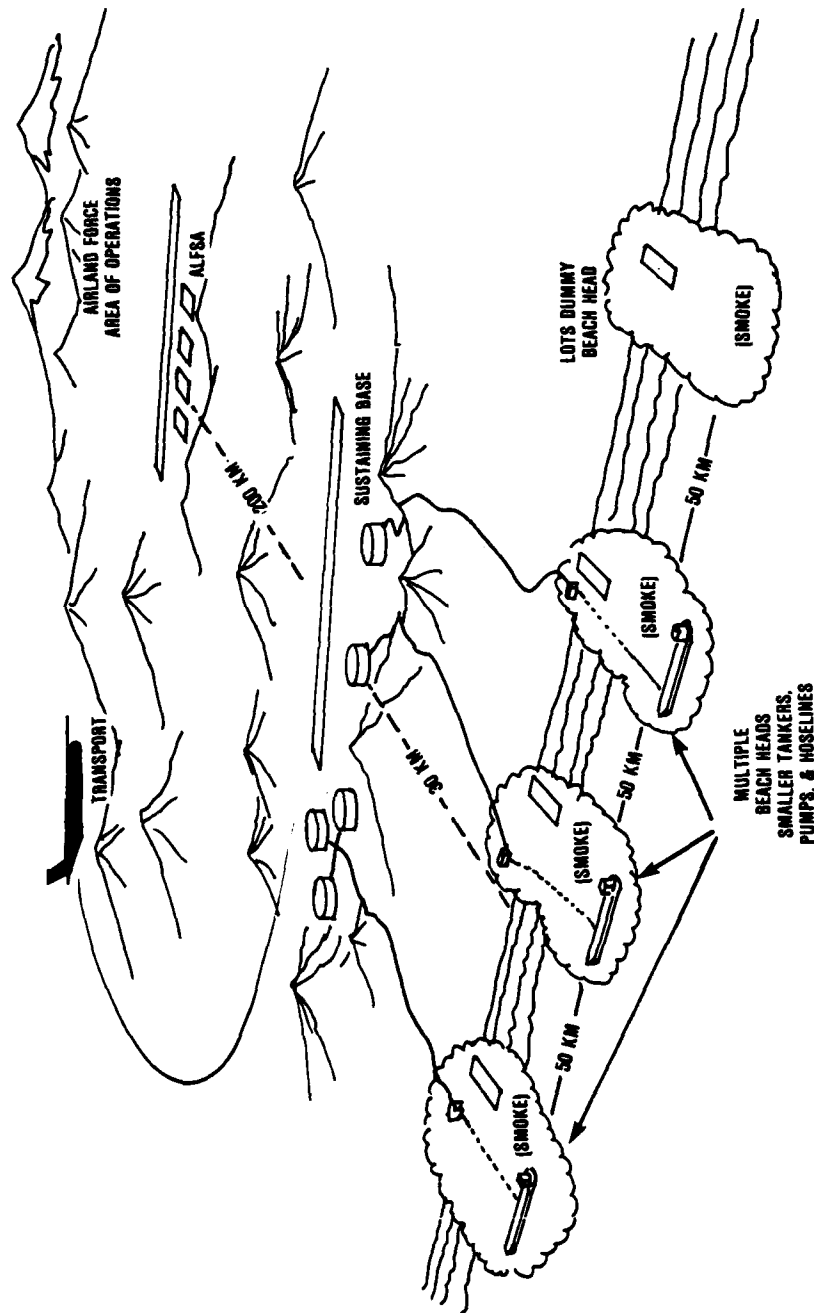


Figure V-3. Future Off-Shore Petroleum Distribution System

## THE BDM CORPORATION

Fueling support activities must be capable of moving rapidly with the combat forces and deploying farther forward to prevent combat units from having to come off the line for resupply.

Supply tankers must be capable of entering the theater, mooring in adverse sea and weather conditions to a previously deployed terminal, and discharging cargo rapidly (3 days or less) in relative safety from attack. Petroleum transfer must be dependable despite rough seas, high winds, strong currents or large tidal changes. However, we must recognize that in the interest of survivability, mooring the tanker in a conventional manner might not be desirable and the supply system must be capable of adapting to theater needs and conditions.

Fuel supply must follow the battle task forces as they move inland and at the same time build up supplies at inland storage areas, especially at a large sustaining base storage area (SBSA) for the AirLand Force. Fuel supplies will move over one or more of these beaches to the base terminal at the SBSA.

### B. SHORTFALLS IN OFF-SHORE SYSTEMS

As discussed in the preceeding section, vulnerability of the off-shore fuel handling system to attack from longer range enemy weapon systems may be a serious deficiency.

Two parts of the system as constituted are the tanker moored off-shore in a relatively fixed position and the on-shore storage tanks. The ship-to-shore pipeline is relatively safe from damage except by overt attack or guerilla operations. Vulnerability varies considerably depending on the scenario and enemy capabilities to mount an attack. Dispersal of on-shore storage to a number of relatively small, widely dispersed tank farms will enhance survivability but will increase the complexity of the POL support system, and will add to cost and operating

## THE BDM CORPORATION

personnel. In terms of tradeoff, it will also likely add to installation time or require additional personnel to install the total system. Tradeoffs must be weighed in the context of the probable scenario and the extent of the potential enemy threat.

Realistically, the amount of petroleum products required by Army 21 and the trend toward the use of larger oceangoing tankers by the Navy and commercial shippers, will lead to delivery of bulk POL into a theater of operations by tankers in the 30,000 to 45,000 DWT class. Even larger tankers, up to 70,000 DWT, are being planned for by the Army and Navy. These tankers will draw up to 45 feet of water as compared to today's MSC tankers which draw approximately 35 feet of water. Longer times required to discharge bulk liquid cargoes will result in dictating longer periods during which the tankers will be moored in a fixed location. Satellite surveillance and other sophisticated methods of target identification will lead to early targeting of the moored tankers by the opposing forces using longer range missiles.

To improve upon the current system and provide the capacity for mooring larger tankers, two systems are under development to satisfy near term contingency requirements. These requirements are predicated on rather specific geographical and environmental conditions. The degree to which improvements in near term mooring systems will be adequate to satisfy long-term needs in all theaters of operation must be determined from future testing.

To meet current contingency planning requirements, up to 30,000 barrels (1.26 million gallons) per day of bulk liquid must be transported up to 4 miles offshore. To satisfy these near term requirements two pipeline systems are being developed: a 1 mile pipeline and a 4 mile pipeline. The 1 mile pipeline will be capable of delivering up to 600 gpm. The 4 mile pipeline will employ one or more lines capable of providing up to 1200 gpm. Consideration is being given to using a pump with a capacity of 800 gpm. The need to transport several different petroleum products through the same, or adjacent, pipeline will place additional demands on the system.



## THE BDM CORPORATION

Current methods for temporary, or rapid deployment, fuel storage on-shore in an undeveloped theater specify a period of 72 hours to install the system. This is the storage provided by a tactical marine petroleum terminal (TMPT) with a capacity of 3,000,000 gallons. Since a complete TMPT on-shore portion has never been installed there is some speculation as to whether or not it can be accomplished in 72 hours. Near term improvements in the system are in progress and will provide a tactical petroleum terminal (TPT) with a storage capacity of 3,600,000 gallons.

Inasmuch as the on-shore storage takes place in collapsible fabric tanks, the system is vulnerable to failure or damage due to enemy action. Rupture of the tanks can easily result from shrapnel damage or small arms hits. Thus, protection and security of the storage area is essential. Also, due to the relatively large amount of acreage of level terrain needed for the system, siting the storage area poses some special problems where heavily wooded or hilly areas are close to the shoreline. Heavily wooded areas would not necessarily preclude installation of the storage system, and would provide desirable concealment. However, preparation of the area for system installation would require more time and heavy equipment. To enhance long term on-shore storage capacity, Belvoir Research and Development Center is conducting exploratory research through contract for development of a 25,000 to 50,000 bbl fuel storage tank. The tank is expected to be relatively low profile gravity wall filled with dirt and lined with a coated fabric.

### C. ALTERNATIVE CONCEPTS

#### 1. Rapid Deployment, Lightweight SPM

One alternative to current and near term off-shore fuel handling systems is a concept similar in function but simpler in design, lighter in weight and more highly deployable. A dedicated LCU or appropriate size landing craft with ocean going capability could be outfitted to transport

and support the total installation. A single point mooring (SPM) buoy weighing less than 60 tons would be transported and launched by the LCU. With appropriate modification of the cargo deck the buoy could be launched and set by the LCU without the need for heavy lifting equipment. Chain mooring would be self-contained with the buoy installation and placed in position by the LCU. Trained divers could be used to assist in underwater work as necessary. Connections between the tanker and the SPM for POL discharge could be made above the surface of the water before the SPM was set. Ship-to-shore transport of the fuel would be accomplished through flexible 6 or 8 inch aluminum or plastic pipeline stored on reels mounted vertically or horizontally on the deck of the LCU. The pipeline would be laid directly to the shore by the LCU with the aid of a smaller watercraft and tractor on the beach. A LACV-30 might be used as a substitute for both the smaller watercraft and tractor, however the tow-bar pull of an air cushion vehicle is limited both on land and water. POL would be discharged from the tanker to a connection on the SPM and then to the shoreline via the flexible pipeline. Pumping would be accomplished using the tankers main cargo pumps. Typical pumps on commercial and MSC tankers are capable of pumping at flow rates of 4000 to 5000 gallons per minute through 10 and 12 inch manifolds. This would be considerably reduced when pumping through 6 and 8 inch pipeline.

The main advantages of this alternative are improved deployability and a manpower savings in system installation. Relatively little gain would be achieved in survivability through this alternative.

## 2. High Mobility Transfer

A second alternative concept would employ portable bulk fuel tanks on the deck of an air cushion vehicle (ACV); a LACV-30, the proposed LAMP-H, or the U.S. Navy LCAC for ship-to-shore transport of petroleum products. This method would serve as an expedient at the early stages of amphibious landing, or as a temporary method to satisfy a requirement of short duration. POL would be pumped from the tanker into the portable tanks on the deck of the ACV, transported to shore, and pumped out of the

portable tanks at a discharge point into an on-shore storage system. Permanently installed tanks could also be incorporated into the design of the LAMP-H for carrying large volumes of bulk fuel. Tanks would be filled only when needed. When empty, the built-in tanks would not impose a serious weight penalty on the LAMP-H performance compared with its proposed cargo capacity. Using this concept, a fleet of four LACV-30s could transport 1500 barrels of fuel in a 20 hour day. Two Navy LCACs, with a higher speed and larger cargo capacity, could transport nearly 1800 barrels of fuel in a 20 hour day. The use of the ACV would also enable the fuel to be discharged at a variety of locations without intermediate pumping stations being established.

A significant advantage of this alternative is a system which is flexible with regard to dispersal of amphibious operating areas, geography, and required volumes of fuel. Due to the high degree of mobility inherent in such a system it is far less vulnerable than one with a fixed tanker discharge position. The tanker could continue to maneuver within certain limits and fuel would be transferred to the shuttling air cushion vehicles with the tanker underway at slow speeds. Survivability of the off-shore portion of the system is considerably enhanced. The system could be quickly and easily modified to adapt to changing tactical requirements. Relative invulnerability of air cushion vehicles to underwater and surface-moored enemy mines would also enhance survivability. However, such a system could not be expected to operate as the primary ship-to-shore transport system for more than a limited number of days. Volume requirements could be met over a longer period only by the employment of a large fleet of ACVs which would entail many support personnel, extensive maintenance and repair facilities for the ACVs, and high operating costs. Additionally, LCAC and LACV-30 craft will be in high demand because of their superior performance and competition for ACV resources will be great.

3. Expedient On-Shore Storage

Several alternative concepts for storage of bulk fuel on-shore are worthy of examination. Temporary storage on-shore could be established by any one or combination of several different means. A rapidly constructed storage tank could be made with earthmoving equipment by excavating an open pit surrounded by a berm constructed of the excavation spoil. The pit would be lined with a fuel-impervious fabric to contain the fuel. The size of the pit would be limited principally by the size of the liner that could be fabricated and handled. The open pit area would be covered by the same fabric used to contain the fuel, to reduce evaporation and keep out impurities. Although some loss of fuel would result from evaporation, the loss could be minimized by devising a simple means of attaching the two pieces of fabric at their edges to provide a partial seal.

Another means of storage would consist of two plastic/fibre reinforced plastic molded hemispheres, or half-cylinders with their ends closed, that could be quickly assembled and sealed by adjoining flanges to provide a storage tank. The shells could be nested one within the other in quantity to reduce storage and handling when not in use. The shells would be relatively light in weight and could be assembled without the use of materials handling equipment. The shell tanks could be placed on heavy duty trailers or transporters before filling to provide greater mobility. A similar means of storage would consist of a rubberized fabric tank placed on an M872-34 ton trailer bed and moved by a M915 tractor. A suitable tank is currently fabricated under the trade name SEALDTANK by Uniroyal in sizes as large as 4500 gallons. These methods of storage would offer a high degree of mobility but limit their application to relatively small POL storage needs.

4. Off-Shore Storage

Off-shore storage provides additional alternatives to bulk petroleum storage in an over-the-shore scenario in an undeveloped theater. A barge sunk to the bottom in relatively shallow water is a ready-made,

rapid means of establishing a storage system which is not dependent upon terrain preparation or a large amount of manpower to assemble. The sunken barge would be less vulnerable to enemy air or artillery attack than floating systems or land-based systems. However, floating barges or tankships offer considerable potential for a large, mobile fuel supply. LASH or SEABEE barges configured for bulk liquid storage could be easily transported to the operational site by their parent ship along with other early logistic support items. Fabrication of tanks conforming to the interior size of a LASH or SEABEE barge could also be accomplished so that any LASH/SEABEE barge could be temporarily used for bulk fuel storage. Figure V-4 illustrates several applications for off-shore storage that were proposed in "An Analysis of Army Logistics Hardware Requirements."

5. Air-Deliverable Fuel Modules

The ability to air deliver a modular fuel package with self-contained pump from a tanker moored off-shore in theater would satisfy the need for a more mobile resupply system in forward areas, and would provide an effective means for reconstituting a damaged fuel distribution system. A dependable air delivery system from a moored tanker to shore would also reduce the need for some on-shore storage. Air delivery by helicopter could be effected direct from the supply tanker off-shore to tactical fueling points and would be highly flexible in changing battle situations. Tanks capable of being filled on board the tanker, air-lifted by helicopter to a designated location and deposited at the location, with an empty tank carried on the return trip to the tanker. Two helicopters in service today are capable of limited performance in such a mission; the CH-53E and CH-47D. Both helicopters, however, have probably reached their limit in growth potential and neither of the two is likely to be in service by the year 2000. The CH-53E is capable of carrying a total cargo weight of 32,000 lbs. externally for a mission radius of 50 nautical miles, or 30,000 lbs. internally for a mission radius of 100 miles. The CH-47D is capable of carrying a total cargo weight of 22,686 lbs. externally or 15,856 lbs. internally for a 30 nautical mile mission

## ALTERNATIVE STORAGE SYSTEMS

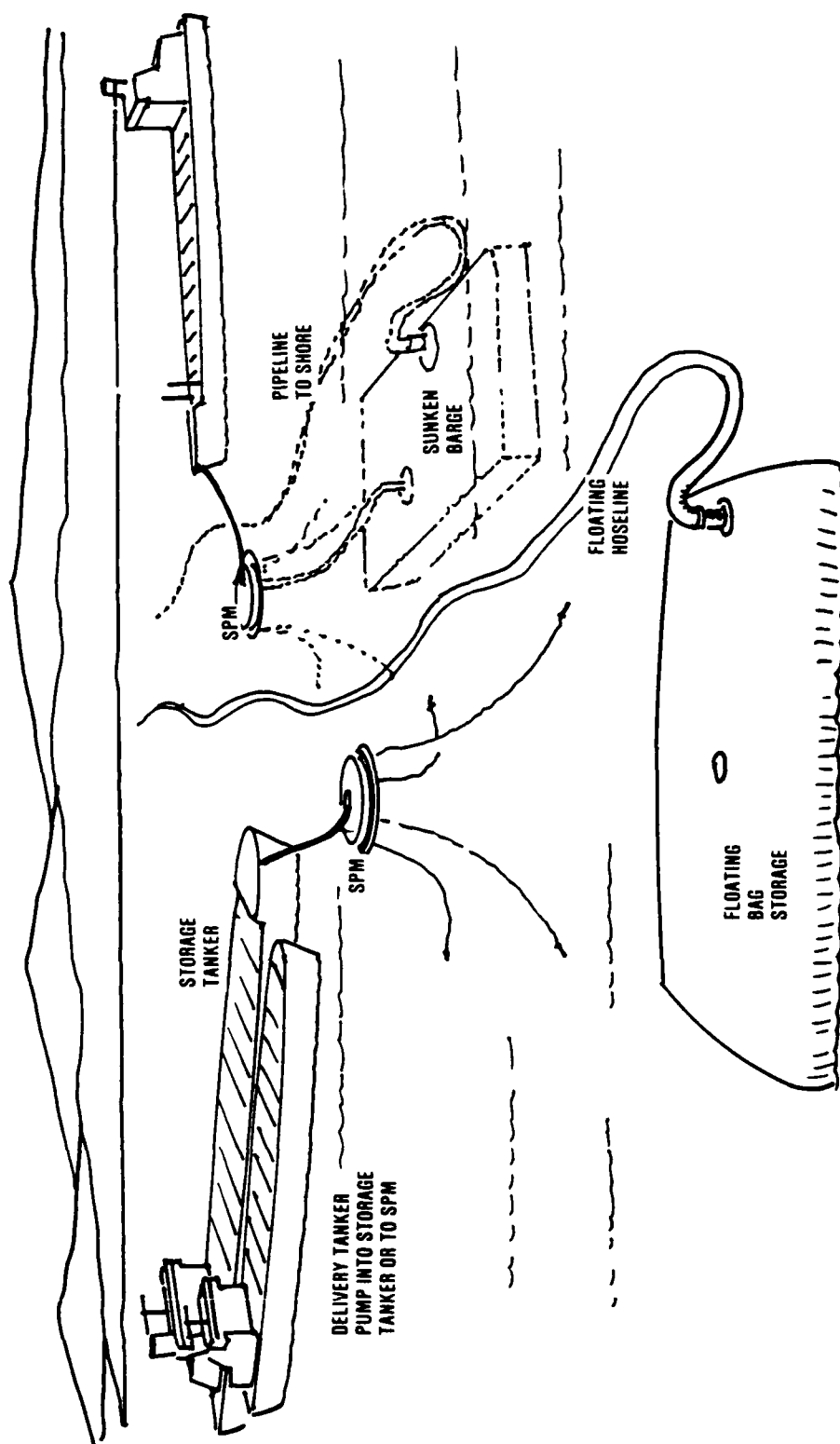


Figure V-4. Off-Shore Bulk Fuel Storage Alternatives

## THE BDM CORPORATION

radius. Using the 3,000 gallon aerial bulk fuel delivery system as a candidate fuel transport system, the CH-53E could carry externally the full 3000 gallon system on pallet with a pump. The CH-47D could carry approximately 2750 gallons in the tank on a pallet with a pump. Neither helicopter could carry the system internally due to limiting dimensions of the cargo space. Although such a system might be acceptable under very limited tactical conditions, it is apparent that it could not begin to satisfy the daily bulk fuel requirement stated by the Army (30,000 barrels per day). Another helicopter being developed for a heavy lift mission is expected to have a payload of 45,000 lbs. This is approximately a 70% increase in performance over the CH-53E. However, successful development, production, and introduction into service in quantity of the heavy lift helicopter is far from assured. If this helicopter becomes operational, it would have the capacity to transport between 5000 and 6000 gallons of fuel on each trip. Assuming a round trip could be made in 10 minutes, this would equate to the same productivity as the current 600 gpm pipeline/hoseline system and would show no real improvement over today's capability. It would offer a more flexible alternative and, consequently, a more highly survivable system.

CHAPTER VI  
CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

Based on the analysis undertaken in this study effort, the following conclusions are drawn:

- (1) The ongoing RDT&E efforts to field an improved over-the-shore fueling system are needed.
- (2) This new fueling system can be assumed to generally meet the physical and technical performance characteristics specified in the Letter Requirements.
- (3) Nevertheless, the performance of the system will still be less than desired, even for the near term. This may be remedied, however, with future product improvements.
- (4) Regardless of such improvements, it is doubtful that any fixed mooring system can survive during the early stages of contingency operations in the Army-21 era.
- (5) A system of over-the-shore refueling is needed which can survive as well as the contingency force during the first 7-10 days or until the lodgment area is secure from threat air and missiles.

B. RECOMMENDATIONS

It is recommended that RDT&E efforts be undertaken on one or more of the following concepts in order to increase the survivability of an over-the-shore refueling system.

- (1) A rapid deployment, lightweight single point mooring (SPM) buoy system employing an LCU or appropriate landing craft to deploy the system.
- (2) A high mobility transfer system using the LACV-30 with portable storage tanks on deck.



## THE BDM CORPORATION

- (3) A large capacity, built-in fuel tank incorporated in the design of the LAMP-H, now under development.
- (4) Portable tank shells for expedient storage.
- (5) A means for rapidly converting LASH or SEABEE barges to temporary fuel tanks.
- (6) An air-deliverable fuel module transportable by heavy lift helicopter.

**END**

**FILMED**

3-86

**DTIC**